# Carps and Minnows of Iran

## (Families Cyprinidae and Leuciscidae)

**Volume 1: General Introduction and Carps (Family Cyprinidae)**

Brian W. Coad

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**Volume I:**

**General Introduction**
**and**
**Carps**
**(Family Cyprinidae)**

By

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Front cover : *Capoeta coadi*, Iran, Kohgiluyeh and Bowyer Ahmad, Beshar River, after Alwan *et al*. (2016).

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"If you trip over a pebble on the ground, you can be sure that an Englishman put it there" (Persian saying).

As an Englishman I hope there are not too many pebbles in this work, and those that are, were inadvertent.

# Contents

## Acknowledgements

This work is part of a larger study on the freshwater fishes of Iran that has been ongoing for 50 years, presented as scientific papers and a website (www.briancoad.com). The former family Cyprinidae *sensu lato* part of the website is superseded by this book and for minor families by separate papers, and will no longer be updated.

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Faisal, Basrah University, A. W. Al-Hakim, University of Nottingham, L. A. J. Al-Hassan, School of Biological Sciences, University of Auckland, S. A. S. Al Hatimy, Oman Natural History Museum, Muscat, B. A. Al-Hussein Al-Saadi, Iraq, Dr. N. M. Ali, Biological Research Centre, University of Baghdad, Dr. T. S. Ali, University of Basrah, S. Alinejad, Offshore Fisheries Research Centre, Chah Bahar, Iranian Fisheries Research and Training Organization, Jahad-e Sazandegi, H. R. Alizadeh, Iranian Fisheries Research and Training Organization, Jahad-e Sazandegi, Tehran, A. R. Al-Jafery, Department of Hydrobiology, Baghdad, Dr. H. Alkahem, King Saud University, Riyadh, M. A. Al-Mukhtar, Fisheries Research Centre, Ahvaz, Dr. F. S. Al-Nasiri, University of Tikrit, Dr. A. J. Al-Rudainy, University of Baghdad, Iraq, Dr. A. Al-Shamma'a, Ministry of Science and Technology, Iraq, Dr. Nisreen Alwan, Forschungsinstitut Senckenberg, Germany, Drs. A. and S. Alwash, Eden Again Project, Prof. O. A. Amin, Arizona State University, Tempe, M. Amini, Behbehan University of Technology, Dr. F. Andreone, Museo Regionale di Scienze Naturali, Torino, Dr. R. Arai, National Science Museum, Tokyo, G. Arbocco, Museo Civico di Storia Naturale "Giacomo Doria", Genova, Dr. J. D. Archibald, Yale University, Connecticut, Dr. N. B. Armantrout, Portland, Oregon and family, Dr. G. Arratia, University of Kansas, Lawrence, S. Asadollah, Isfahan University of Technology, A. Ashraf, Encyclopædia Iranica, Columbia University, New York, Dr. J. W. Atz, Department of Herpetology and Ichthyology, American Museum of Natural History, New York, A. S. Bachmann, Nature Iraq, Sulaimaniyah, Prof. S. Balik, Ege University, Izmir, Prof. E. Balletto, Istituto di Zoologia, Genova, G. A. C. Balma, Museo Civico di Storia Naturale, Carmagnola, Dr. K. Banister, Fish Section, British Museum (Natural History), London, A. J. Bardhun, Shiraz, D. M. Bartley, Food and Agriculture Organization, Rome, Dr. V. V. Barsukov, Zoological Institute, Academy of Sciences, Leningrad, M. L. Bauchot, Laboratoire d'Ichtyologie générale et appliquée, Muséum National d'Histoire Naturelle, Paris, R. Beck, COFAD GmbH, Tutzing, Dr. W. C. Beckman, Opelousas, Louisiana, H. Barani Beiranvand, Ferdowsi University of Mashhad, Dr. A. Ben-Tuvia, Hebrew University of Jerusalem, Dr. M. Berberian, University of Cambridge, Dr. P. Berrebi, Université Montpellier, Dr. A. D. Berrie, Freshwater Biological Association, Wareham, Dr. E. Bertelsen, Zoologisk Museum, Copenhagen, F. Biglari, Paleolithic Department, National Museum of Iran, Tehran, K. L. Bist, Government Postgraduate College, Gopeshwar, J. Bohlen, Academy of Sciences, Libechov, Dr. J. E. Böhlke, Academy of Natural Sciences, Philadelphia, Dr. K. Borkenhagen, Forschungsinstitut Senckenberg, Germany, Dr. A. H. Bornbusch, Duke University, Durham, Dr. J. Briggs, King Faisal University, Dammam, Dr. J. C. Briggs, Watkinsville, Georgia, Dr. K. E. Carpenter, Food and Agriculture Organization, Rome, V. Chamanara, Gorgan University of Agricultural Sciences and Natural Resources, L. A. Cloutier, Department of the Environment, Tehran, Dr. D. Coffey, Pahlavi University, Shiraz, Dr. M. J. Collares-Pereira, Museu Bocage, Lisbon, Dr. B. B. Collette, National Museum of Natural History, Washington, J. Collins, Food and Agriculture Organization, Rome, Dr. J. T. Collins, Museum of Natural History, University of Kansas, Lawrence, Dr. L. J. V. Compagno, J. L. B. Smith Institute of Ichthyology, Grahamstown, G. H. Copp, Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, Dr. L. Cornwallis, Oxford, S. Cowton, U.S. Army Corps of Engineers, A. S. Creighton, Division of Fishes, Museum of Zoology, University of Michigan, Ann Arbor, Dr. F. Cross, University of Kansas, Lawrence, Dr. E. J. Crossman, Department of Ichthyology and Herpetology, Royal Ontario Museum, Toronto, E. L. Daniel, Encyclopædia Iranica, Columbia University, New York, F. Darvishi, Mazandaran, S. Deeb, American University of Lebanon, Beirut, S. Dehqan-Mediseh, Iranian Fisheries Research and Training Organization, Jahad-e Sazandegi, Ahvaz, Dr. G. B. Delmastro, Museo Civico di Storia Naturale,

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Individual Iranians, too numerous to mention here, kindly enunciated carefully and repeatedly Farsi fish names for my cloth ear. However, it would be remiss not to mention also staff at the Iranian Fisheries Research and Training Organization, Ahvaz including N. Najafpour, Gh. Marammazi, Gh. Eskandari, and M. A. Al-Mukhtar, as well as E. Firouz, Tehran, B. Kiabi and A. Abdoli, Gorgan Agricultural and Natural Resources University, and Y. Keivany, then of the University of Alberta, Edmonton.

And finally, I must thank my wife Sylvie and son Nicholas for supporting me in my obsession with fishes from Iran and Nick for constructing the website on which this book is based.

# General Introduction

## Purpose of the Work

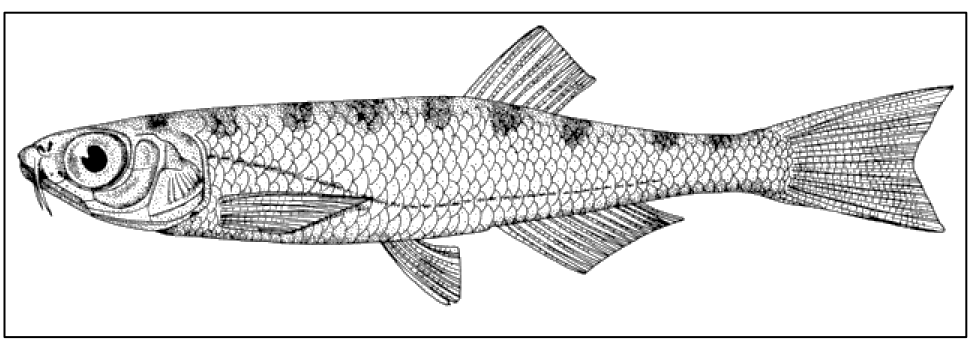
This work attempts to summarise knowledge on two families of cyprinoid fishes in Iran (Families Cyprinidae and Leuciscidae, Suborder Cyprinoidei, Order Cypriniformes, Class Actinopterygii) comprising Carps and Minnows respectively. It is based on materials collected in that country over a period exceeding 170 years, in particular from the 1970s to the present day, and on an analysis of the literature. Some aspects of the work may be rather didactic but hopefully helpful to students new to this discipline.

The family Cyprinidae *sensu lato* has now been divided into several families of which seven occur in Iran. Two are covered here in this work while the Iranian representatives of the five smaller families, Acheilognathidae (bitterlings, one species), Danionidae (danionids, two species), Gobionidae (gobionids, four species, one of which is an exotic), Tincidae (tench, one species) and Xenocyprididae (East Asian minnows, five species, all exotics), are published separately as papers which are available on-line:-

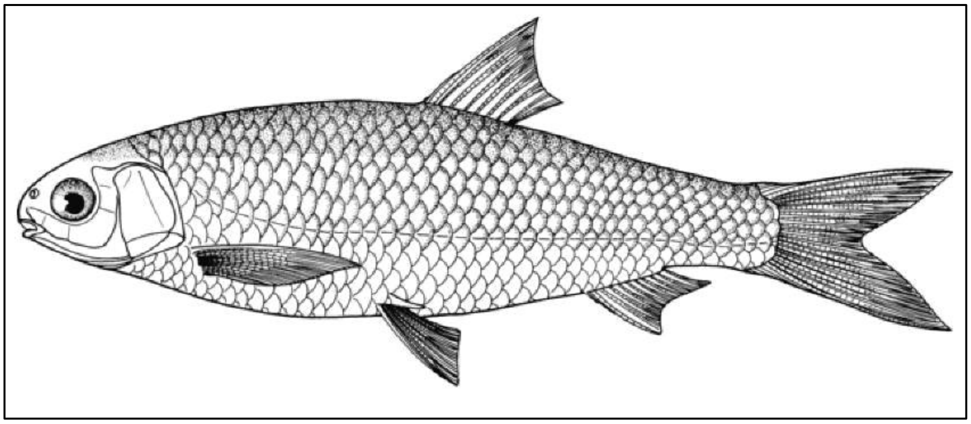
Coad, B. W. 2018b. Review of the danionids of Iran (Family Danionidae). International Journal of Aquatic Biology, 6(4):179-188.
Coad, B. W. 2018c. Review of the bitterlings of Iran (Family Acheilognathidae). Iranian Journal of Ichthyology, 5(4):257-267.
Coad, B. W. 2019b. Review of the gobionids of Iran (Family Gobionidae). Iranian Journal of Ichthyology, 6(1):1-20.
Coad, B. W. 2019c. Review of the tenches of Iran (Family Tincidae). Iranian Journal of Ichthyology, 6(2):82-91.
Coad, B. W. 2020. Review of the East Asian minnows of Iran (Family Xenocyprididae). Iranian Journal of Ichthyology, 7(1):1-67.

Line drawings of these species are given below:-

Family Danionidae

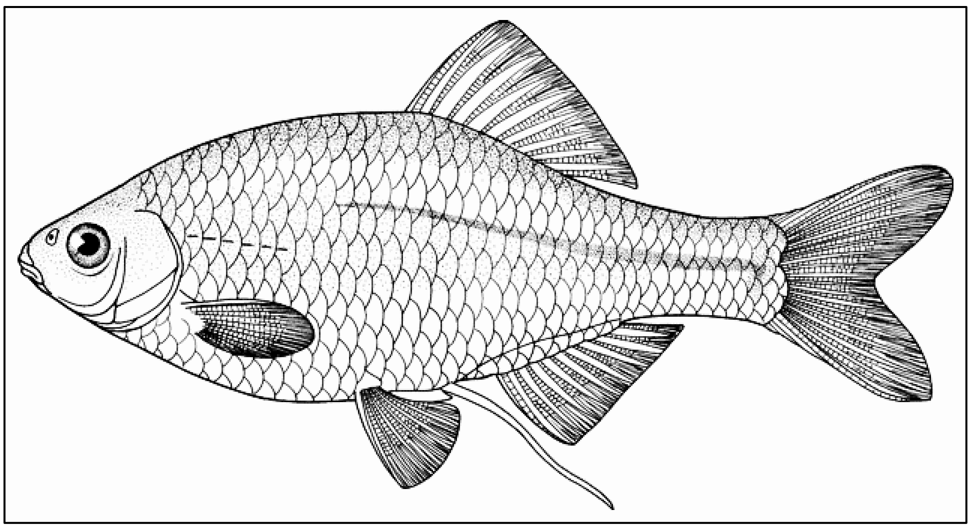


*Barilius mesopotamicus,* Susan Laurie-Bourque @ Canadian Museum of Nature.



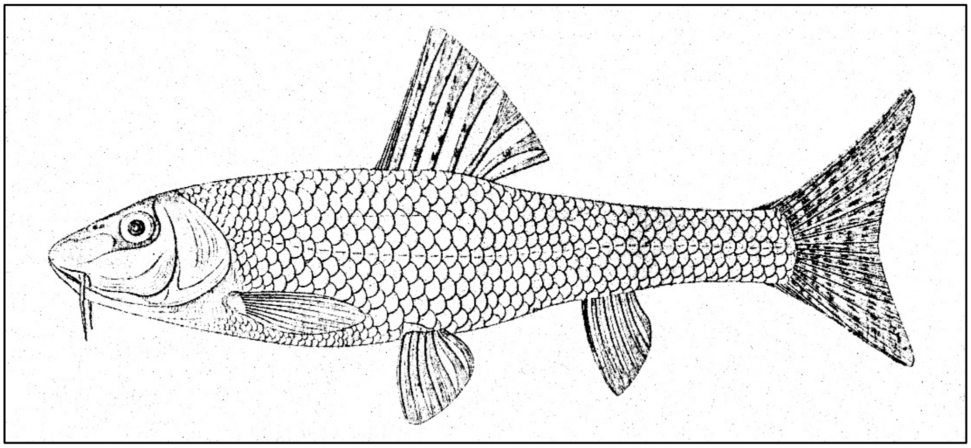
*Cabdio morar,* Susan Laurie-Bourque @ Canadian Museum of Nature.

## Family Acheilognathidae

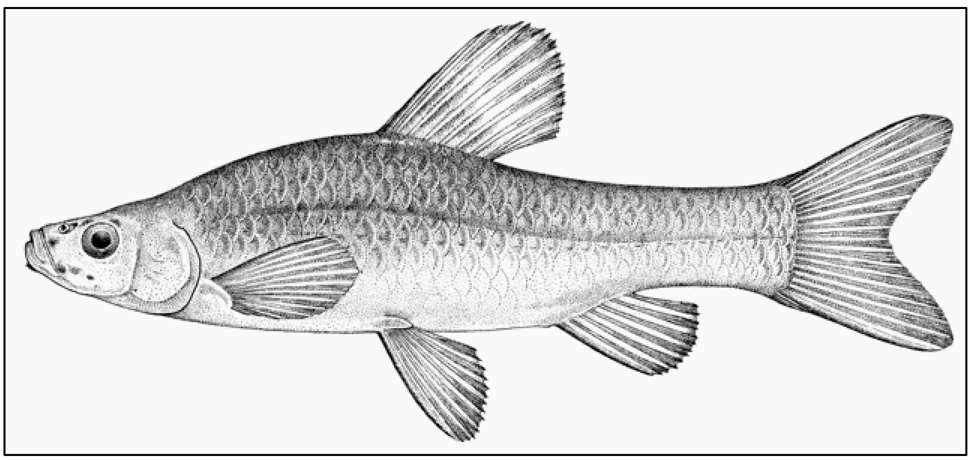


*Rhodeus amarus*, Susan Laurie-Bourque @ Canadian Museum of Nature.

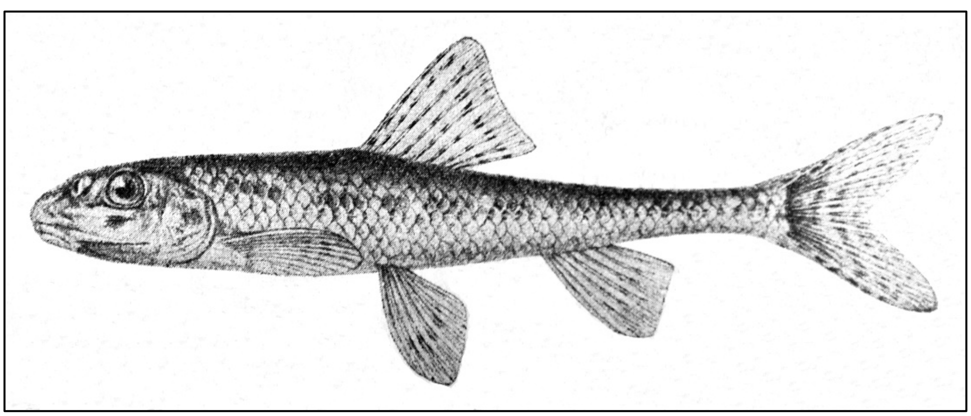
Family Gobionidae



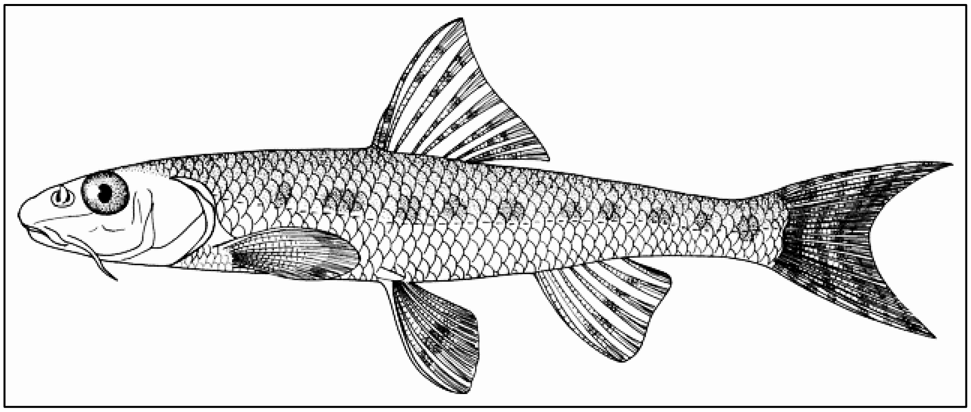
*Gobio nigrescens*, after Keyserling (1861).



*Pseudorasbora parva* (exotic), Charles H. Douglas @ Canadian Museum of Nature.

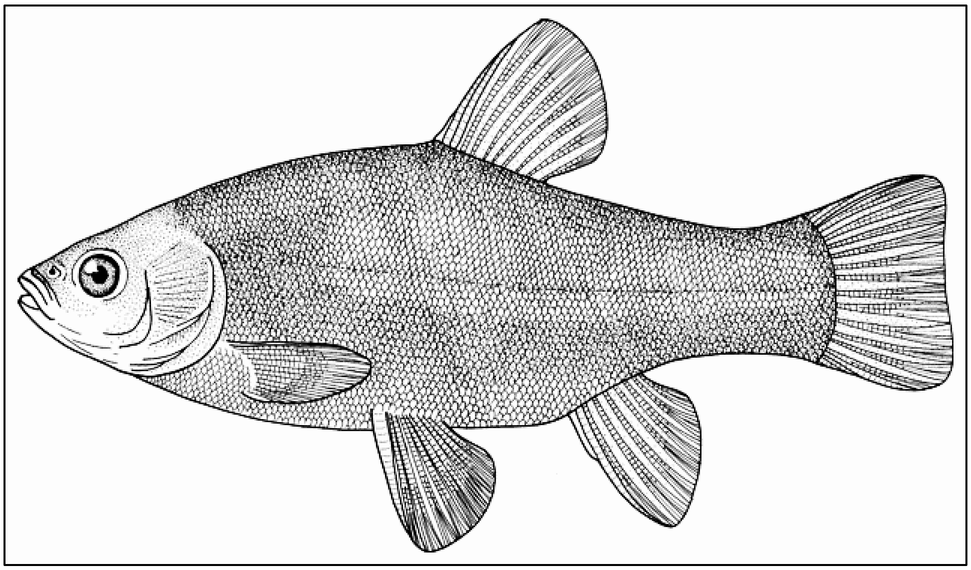


*Romanogobio macropterus*, after Berg (1932b).



*Romanogobio persus*, Susan Laurie-Bourque @ Canadian Museum of Nature.

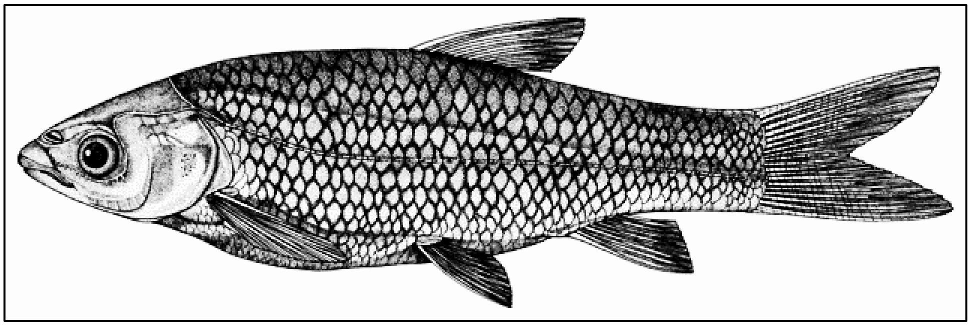
Family Tincidae



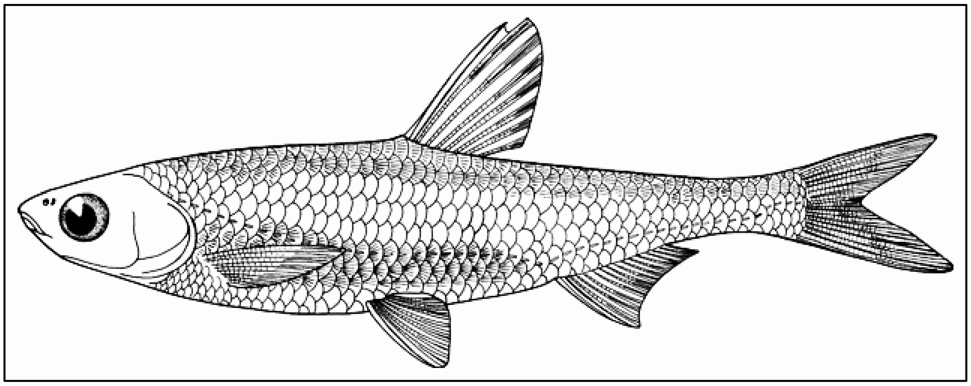
*Tinca tinca*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Xenocyprididae

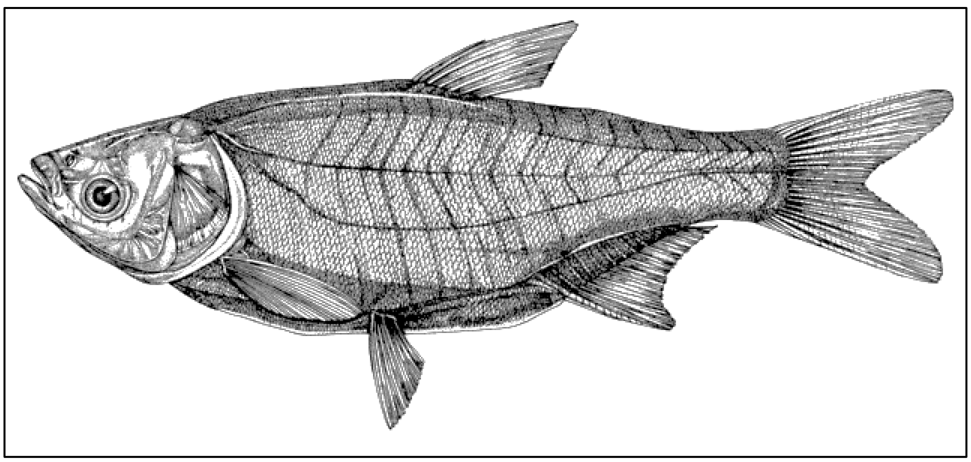
Members of this exotic family are called “Chinese carps” and figure prominently in aquaculture. The common carp, *Cyprinus carpio*, of the Family Cyprinidae treated herein is also a “Chinese carp”, introduced to Iran but also native.



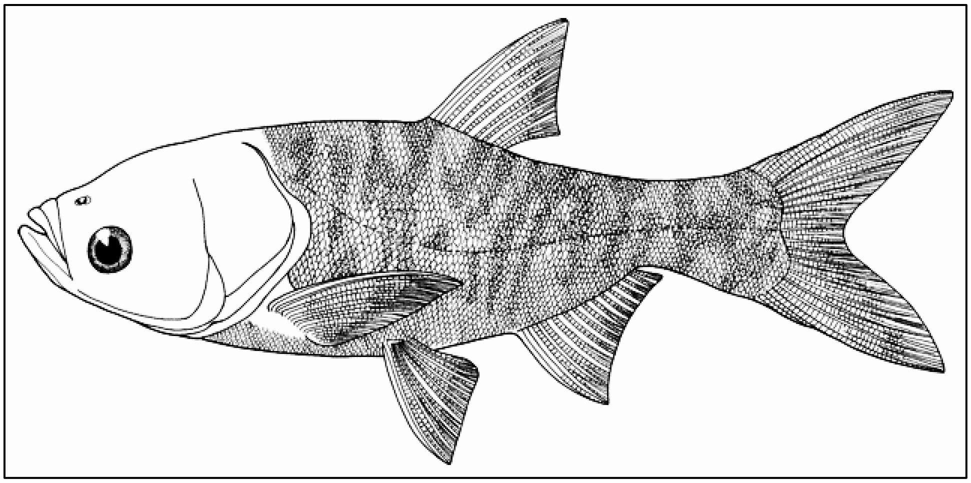
*Ctenopharyngodon idella*, Susan Laurie-Bourque @ Canadian Museum of Nature.



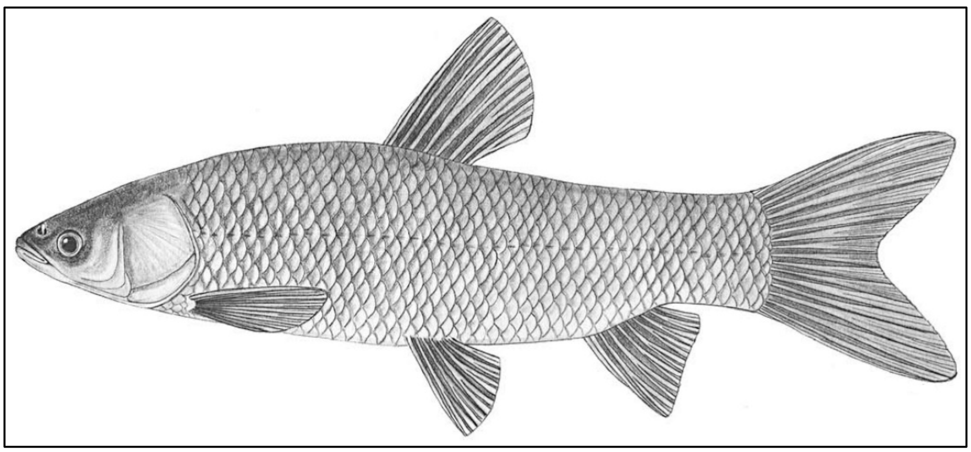
*Hemiculter leusisculus*, Susan Laurie-Bourque @ Canadian Museum of Nature.



*Hypophthalmichthys molitrix*, Susan Laurie-Bourque @ Canadian Museum of Nature.



*Hypophthalmichthys nobilis*, Susan Laurie-Bourque @ Canadian Museum of Nature.



*Mylopharyngodon piceus*, after Schofield (2005).

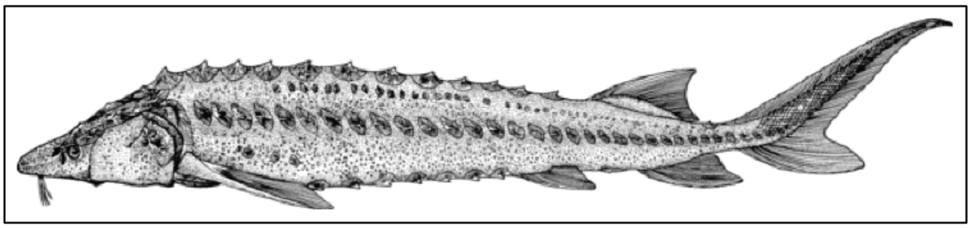
Older works cited in this book referred to cyprinids or Cyprinidae in the wider sense and some of these have been left as in the original, especially if the species referred to is a cyprinid *sensu stricto*. The term cyprinid now refers strictly to the Carps (Cyprinidae). Cyprinoidei or cyprinoids refers to all the families formerly in Cyprinidae *sensu lato* and these terms have been used where appropriate while the original source refers to Cyprinidae or cyprinids. Carp refers to the family Cyprinidae (and formerly to all the families now separated from true Cyprinidae), as a short form for the common carp (*Cyprinus carpio*) - usually obvious from the context, and to carp culture which may involve cyprinoids from another family such as some of the Chinese carps, again usually obvious from the context (see Coad, 2020).

Recent major changes in cyprinoid taxonomy involving species found in Iran include the synonymy of such genera as *Acanthalburnus* with *Acanthobrama*, *Aspidoparia* with *Cabdio*, and *Aspius* with *Leuciscus*. Much earlier literature has a catchall genus *Barbus*, with many species now assigned to other genera namely *Arabibarbus*, *Carasobarbus*, *Luciobarbus* and *Mesopotamichthys*. Members of the genus *Squalius* in Leuciscidae were formerly in the genus *Leuciscus*. Readers consulting older literature should be aware that species may appear under these older genera. Species biology discussed in this text may well appear under the more recent name, not the older one that appears in the literature source, although usually the original name is

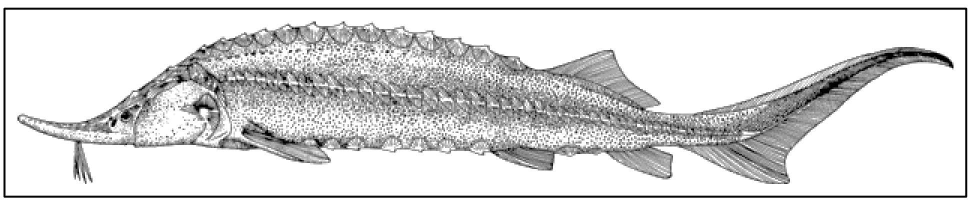
cited with the newer name in parentheses. Later works will have the modern name and this is not cited but implied.

The **General Introduction** serves both volumes of this work as well as the five smaller families and contains several explanatory sections. These sections include methods of counting and measuring characters, a description of the environment and relevant data on fishes, a history of research, and a summary of fisheries. Reference is made to other families of fishes in Iran for comparative purposes, e.g., relative importance of fisheries, biology, etc. A selection of line drawings representative of these other families is given below:-

Family Acipenseridae (sturgeons)

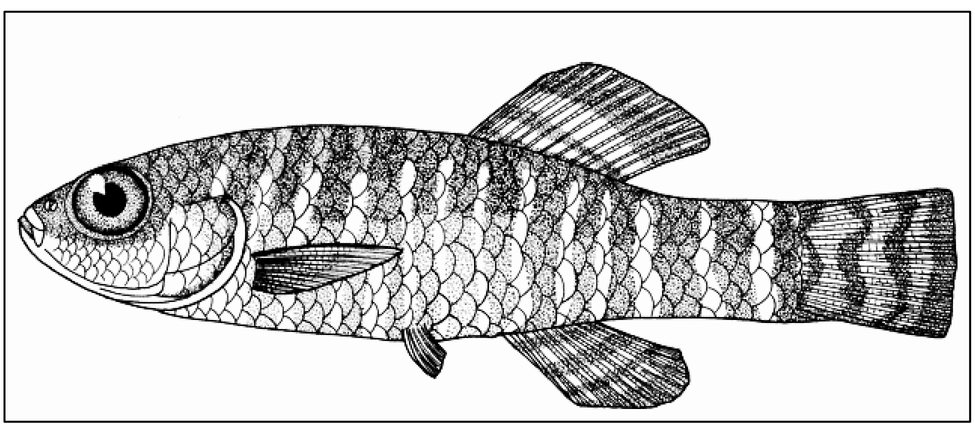


*Acipenser persicus*, Susan Laurie-Bourque @ Canadian Museum of Nature.



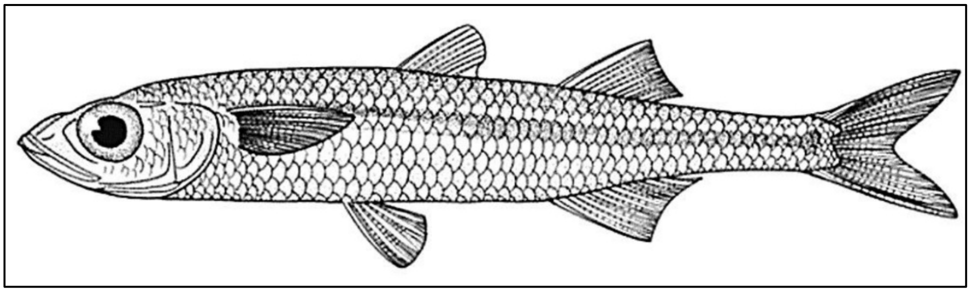
*Huso huso*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Aphaniidae (Oriental killifishes)



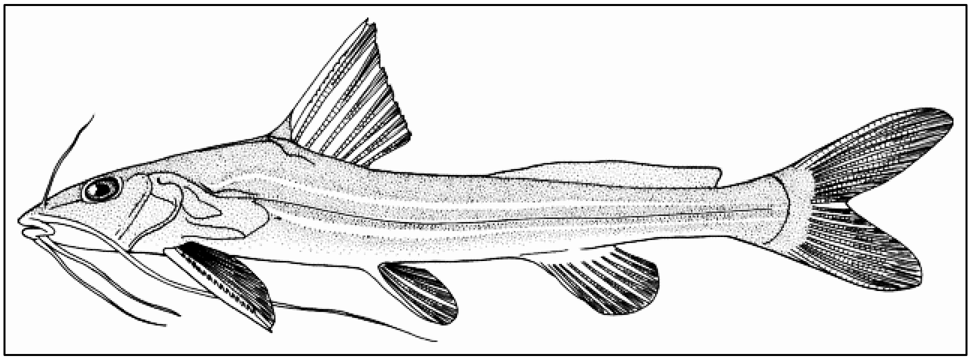
*Esmaeilius persicus*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Atherinidae (silversides)



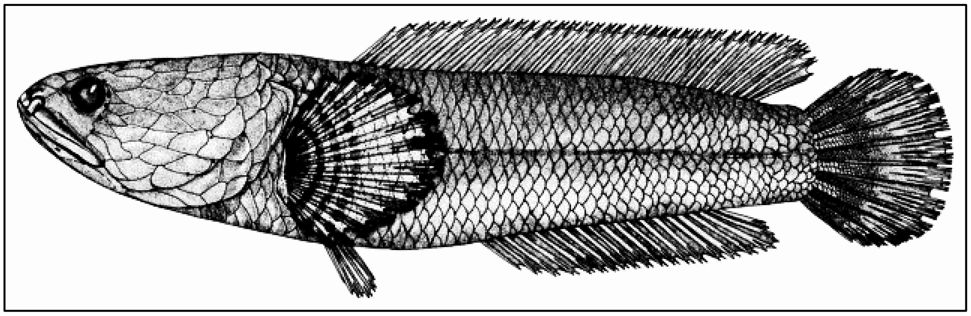
*Atherina caspia*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Bagridae (bagrid catfishes)



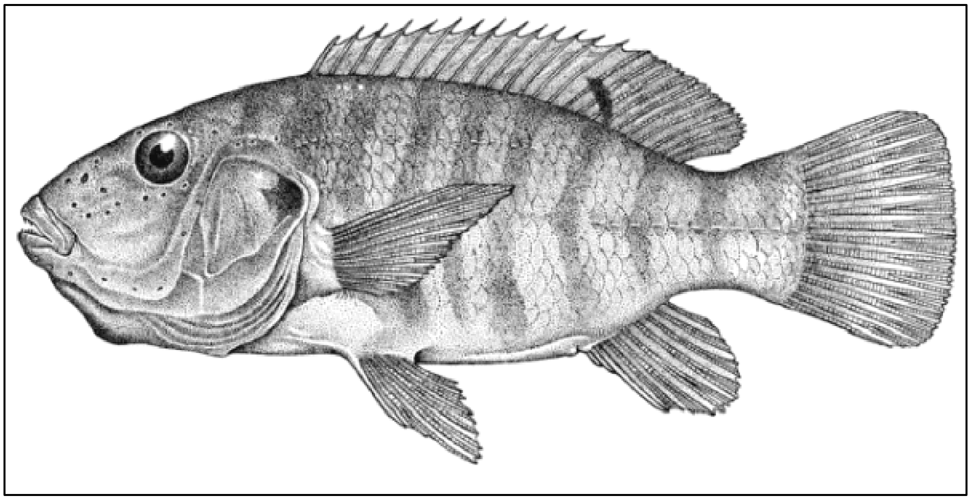
*Mystus pelusius*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Channidae (snakeheads)



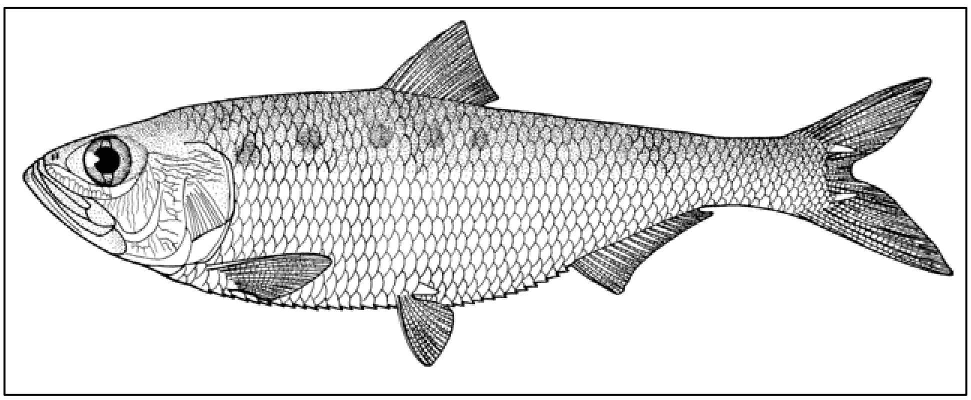
*Channa gachua*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Cichlidae (cichlids)

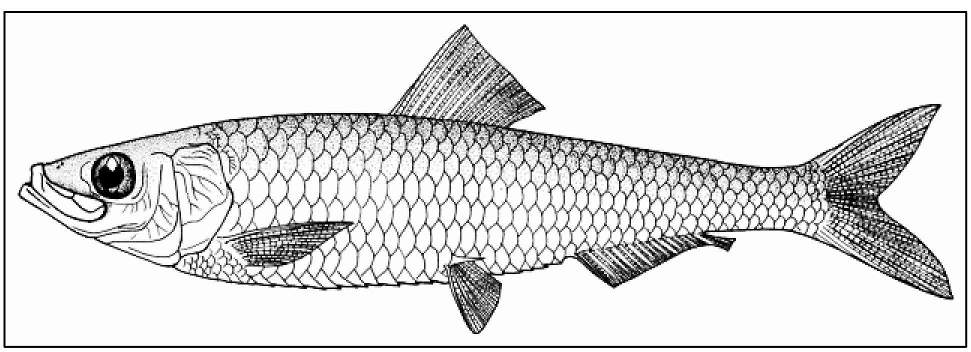


*Iranocichla hormuzensis,* Charles H. Douglas @ Canadian Museum of Nature.

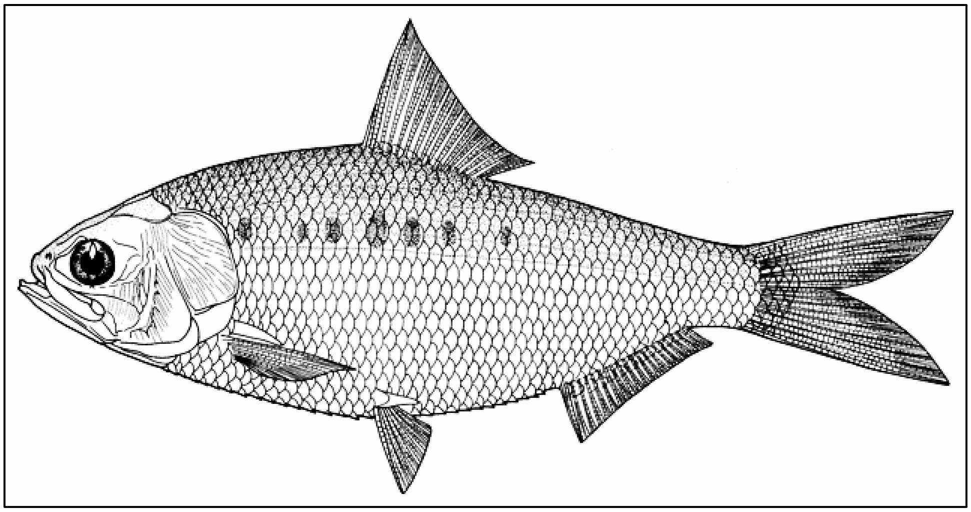
Family Clupeidae (herrings)



*Caspialosa caspia,* Susan Laurie-Bourque @ Canadian Museum of Nature.

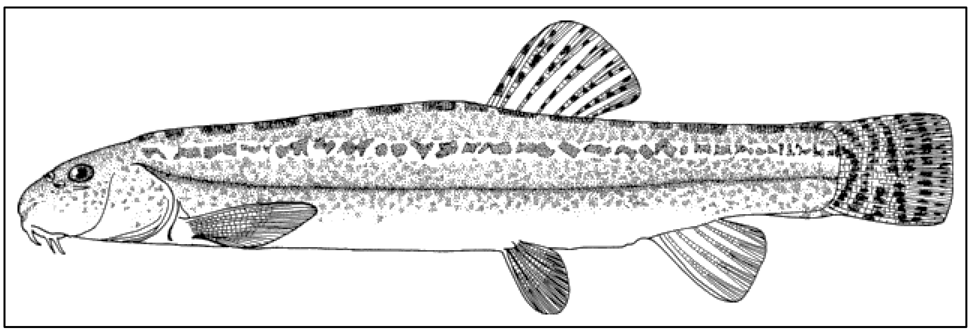


*Clupeonella caspia,* Susan Laurie-Bourque @ Canadian Museum of Nature.



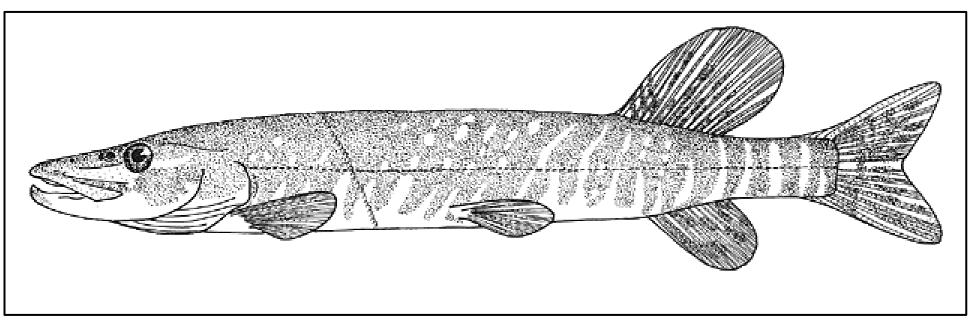
*Tenualosa ilisha*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Cobitidae (longfin loaches)



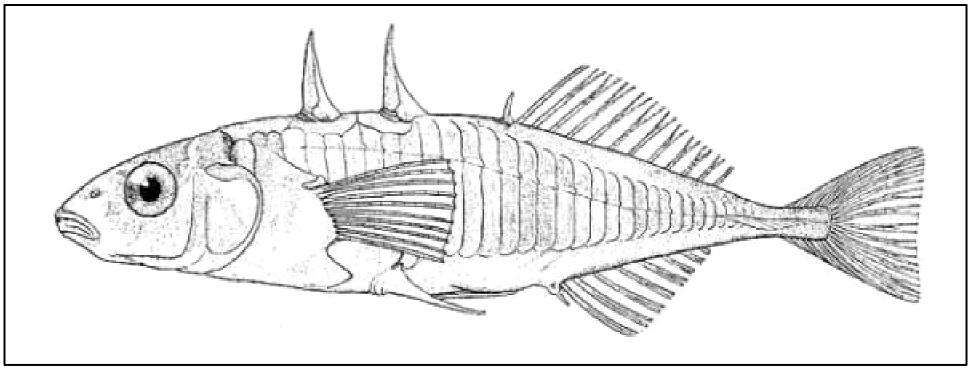
*Cobitis linea*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Esocidae (pikes)

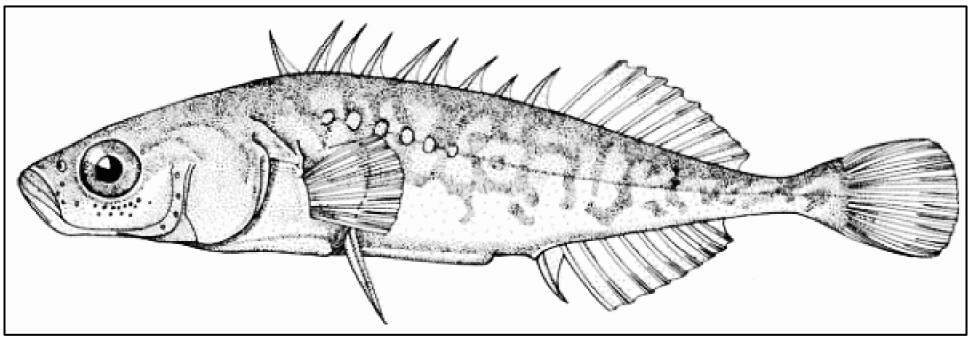


*Esox lucius*, Sally Gadd @ Canadian Museum of Nature.

Family Gasterosteidae (sticklebacks)

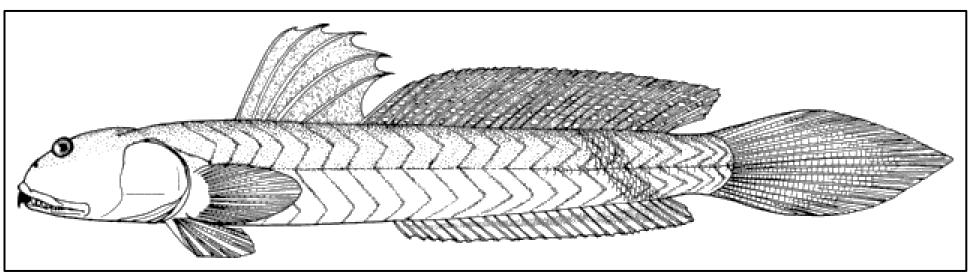


*Gasterosteus aculeatus*, Susan Laurie-Bourque @ Canadian Museum of Nature.

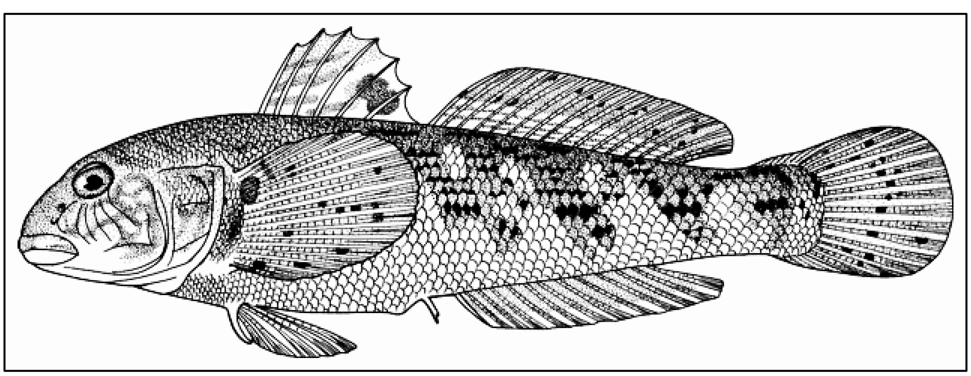


*Pungitius platygaster*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Gobiidae (gobies)

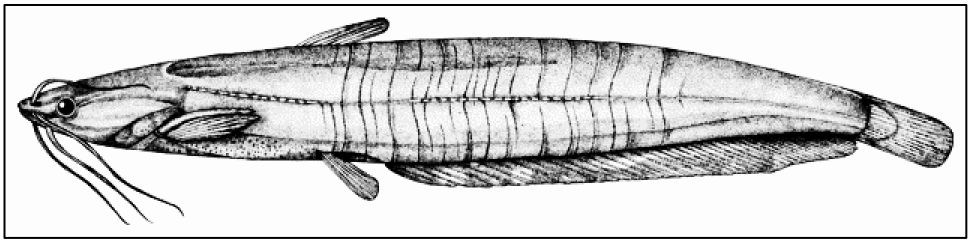


*Boleophthalmus dussumieri*, Susan Laurie-Bourque @ Canadian Museum of Nature.



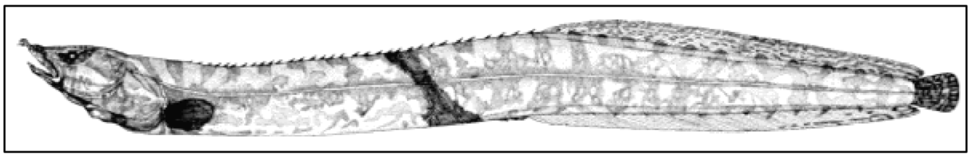
*Neogobius melanostomus*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Heteropneustidae (airsac catfishes)



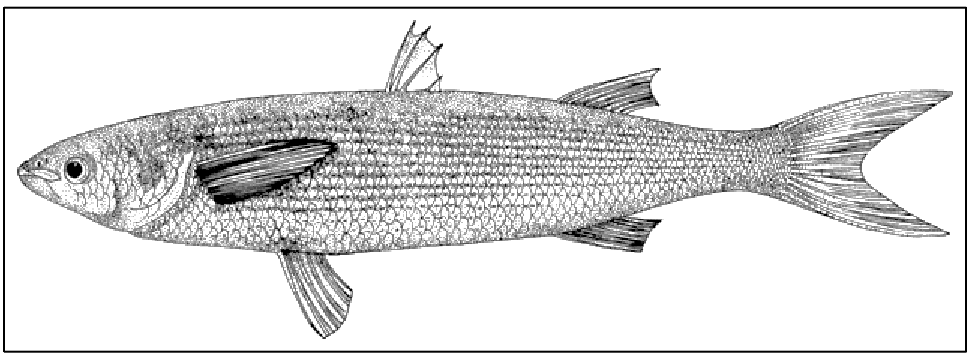
*Heteropneustes fossilis*. Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Mastacembelidae (spiny eels)

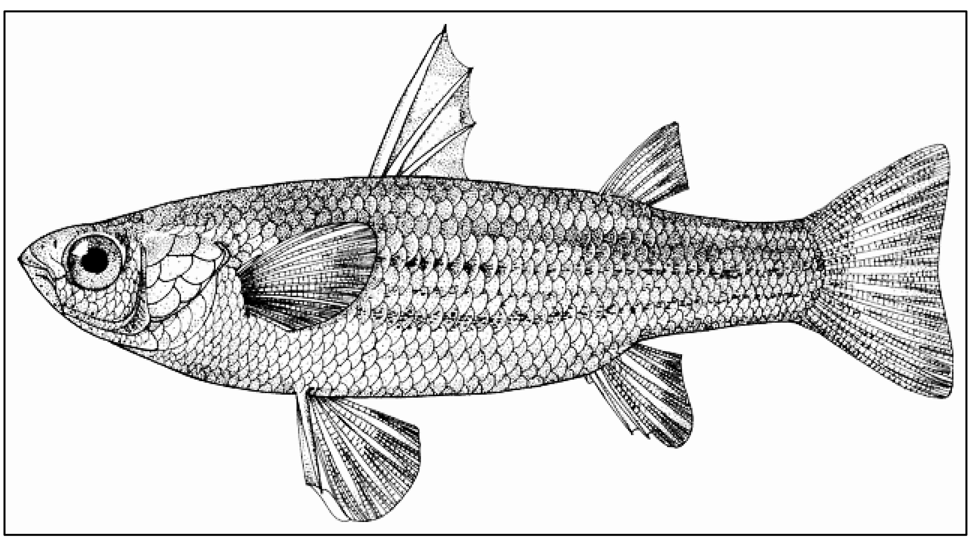


*Mastacembelus mastacembelus*, Charles H. Douglas @ Canadian Museum of Nature.

Family Mugilidae (mullets)

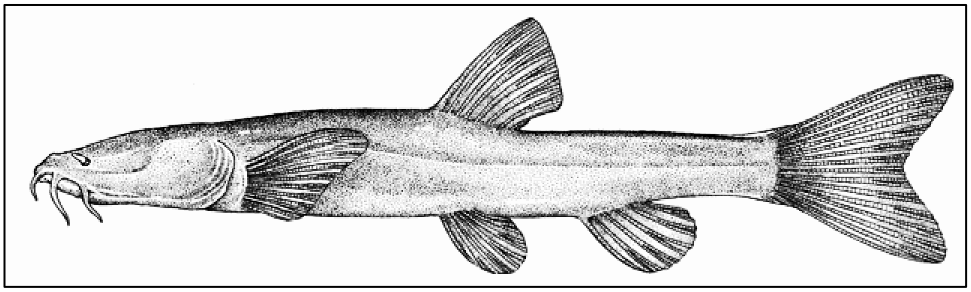


*Chelon auratus*, Susan Laurie-Bourque @ Canadian Museum of Nature.

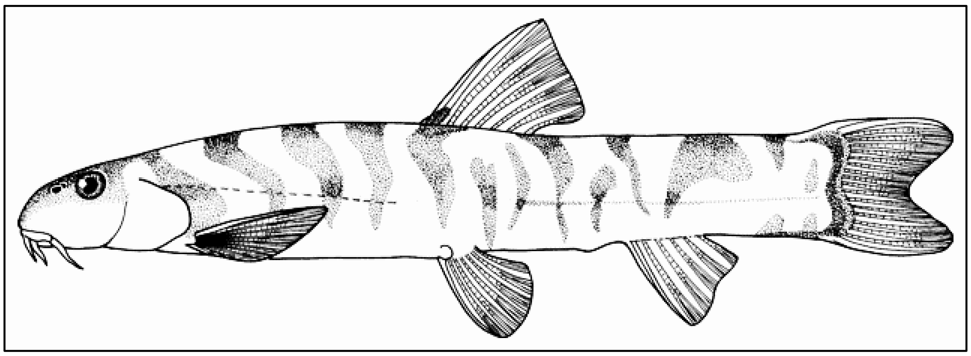


*Planiliza abu*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Nemacheilidae (brook loaches)

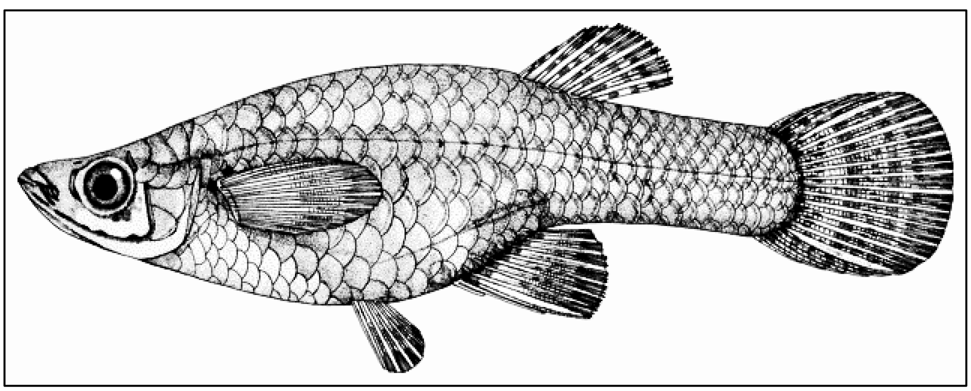


*Eidinemacheilus smithi*, Charles H. Douglas @ Canadian Museum of Nature.



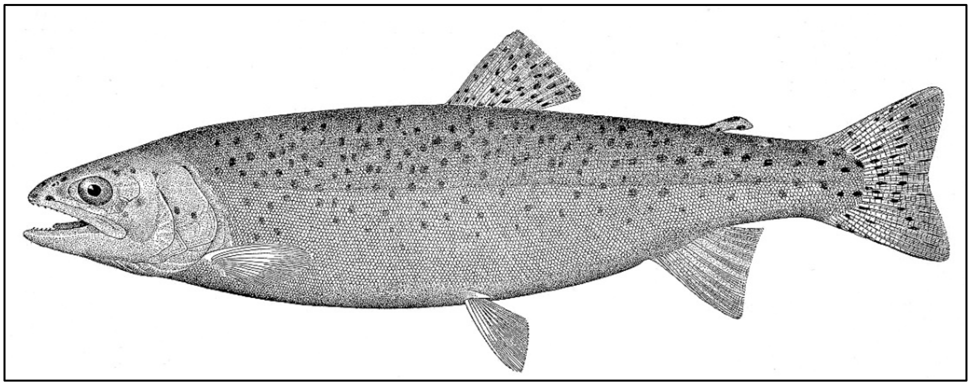
*Paraschistura bampurensis*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Poeciliidae (livebearers)

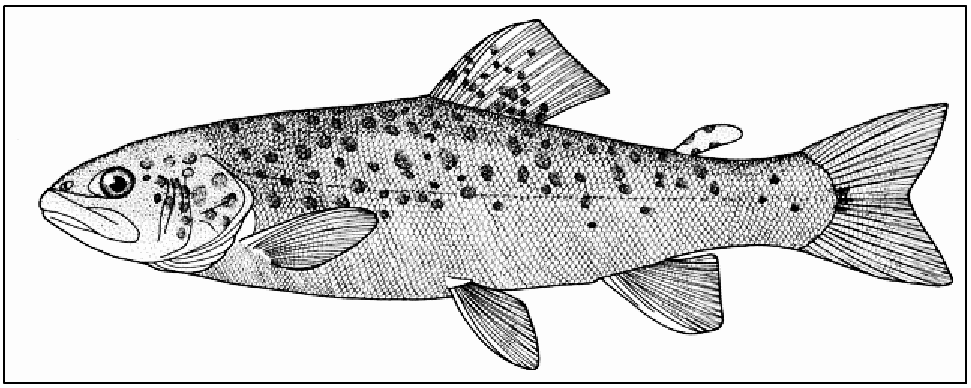


*Gambusia holbrooki*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Salmonidae (trouts and salmons)

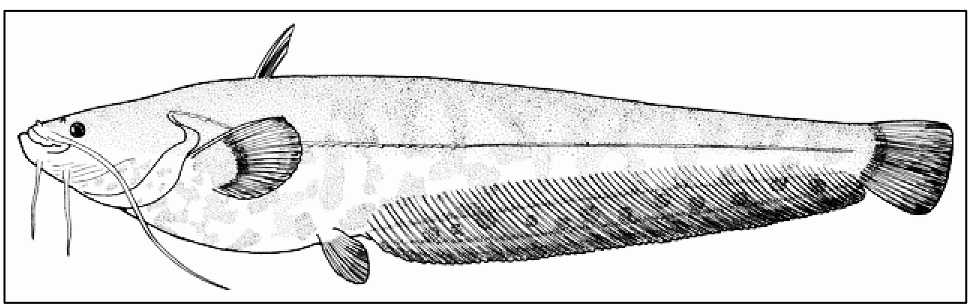


*Oncorhynchus mykiss*, after Brice (1898).

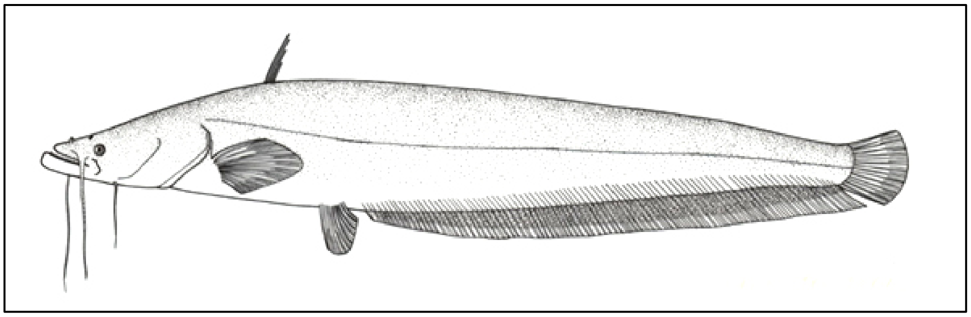


*Salmo caspius*, Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Siluridae (sheatfishes)

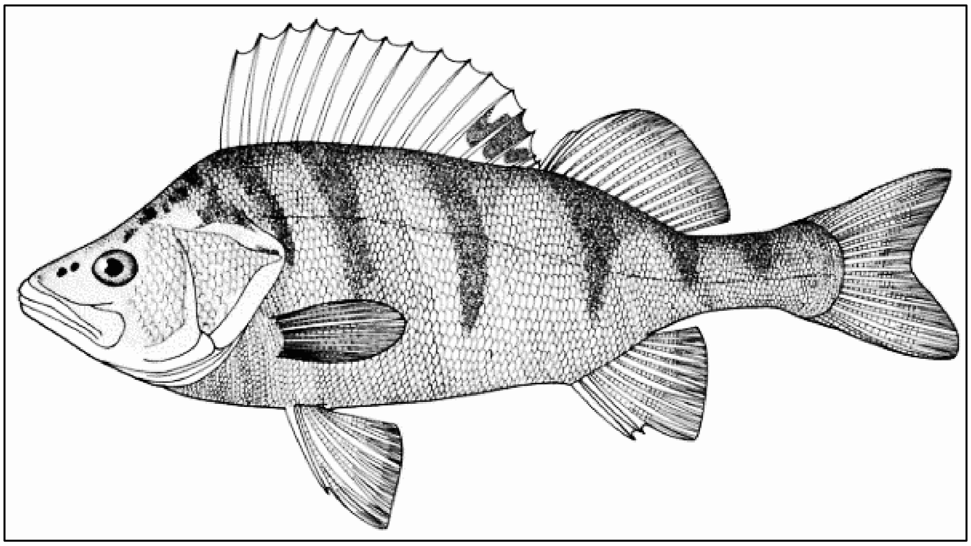


*Silurus glanis*, Susan Laurie-Bourque @ Canadian Museum of Nature.

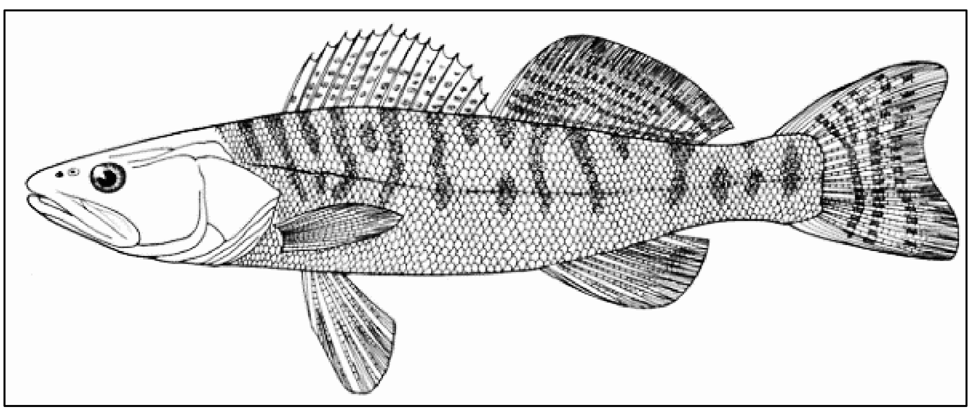


*Silurus triostegus*, Susan Laurie-Bourque @ Canadian Museum of Nature.

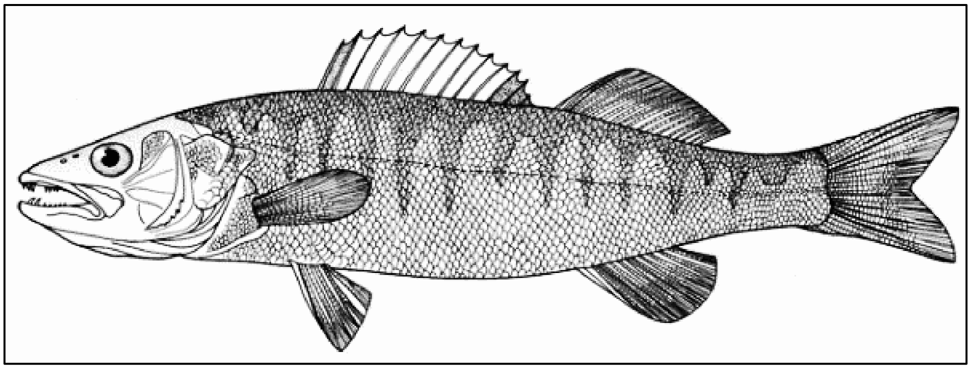
Family Percidae (perches)



*Perca fluviatilis*, Susan Laurie-Bourque @ Canadian Museum of Nature.

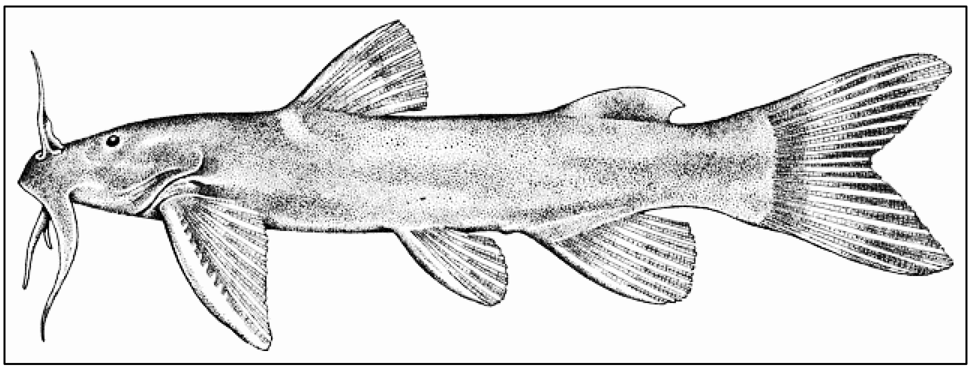


*Sander lucioperca*, Susan Laurie-Bourque @ Canadian Museum of Nature.



*Sander marinum,* Susan Laurie-Bourque @ Canadian Museum of Nature.

Family Sisoridae (sisorid catfishes)



*Glyptothorax silviae*, Charles H. Douglas @ Canadian Museum of Nature.

The **Identification Keys** serve to determine the species, identifying genera and then species in the more speciose genera.

**Checklists** summarise the fauna and lists species from neighbouring countries and basins that may eventually be found in Iran.

A section on **Biodiversity** examines these fishes in terms of drainage basins and ecoregions, and is given for both families.

The bulk of the text is the **Species Accounts** which serve to identify, describe and outline the distribution of each species. Each **Species Account** is comprised of the following parts:- a general description of the genus, illustrations of the species including line and colour drawings and photographs, the scientific name, common names, systematics, key characters, morphology, sexual dimorphism, colour, size, distribution, zoogeography, habitat, age and growth, food, reproduction, parasites and predators, economic importance, experimental studies, conservation, and sources.

The general description of the genus covers distribution, number of species world-wide, number of species in Iran, general morphology, taxonomic comments if any, and general biology.

Each species account is headed by the scientific name in italics (and also in bold for emphasis). Two authors are separated by "and" and the author is separated from the date by a comma. The "and" is often now replaced by the ampersand symbol (&) and the comma is not used. Either system is fairly clear in meaning however. Older original descriptions often capitalised the trivial or species name and, when this is first mentioned in the **Systematics**

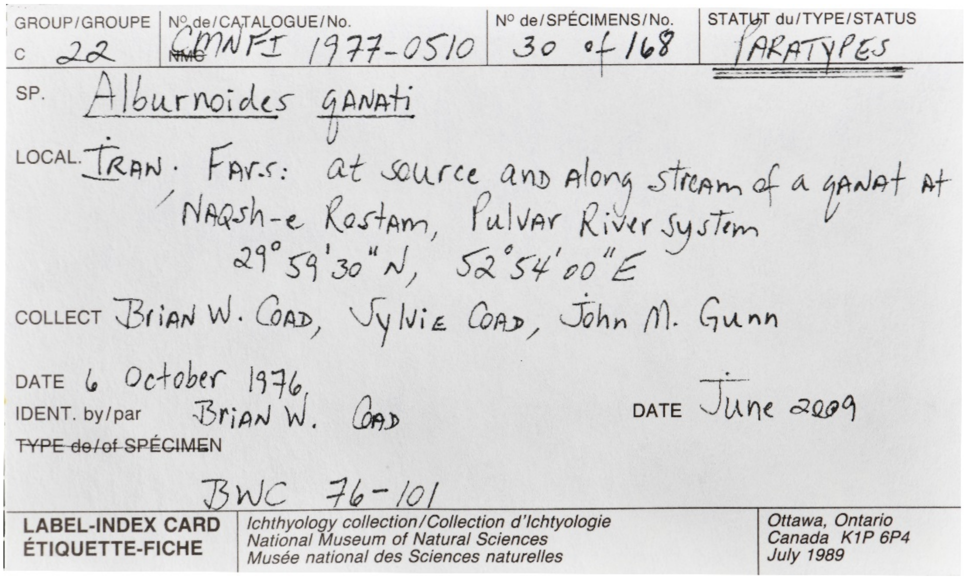
section, this is followed. Later, the standard lower case is used. Not all original descriptions were seen so this may not be uniformly correct. Sources such as the *Catalog of Fishes* use the lower case for the original species name.

Illustrations include line drawings which serve to highlight features not always visible in live photographs. Quality varies and illustrations from some older works are included despite low quality (only photocopies available) to show historical descriptions and/or body form. Some historical drawings, e.g., Heckel's works, were horizontally reversed so the fish faces left for general consistency. Note also some flank scales depicted by Heckel have a broad focal area, rather than a narrow one, and are atypical scales that have been damaged and regenerated. The scientific name on illustrations may be the latest version, the original source having used an older name. Occasionally, the original name is given first or in parentheses for clarity of the source. Illustrations in the **Systematics** section use the original, type description, name. Photographs of older types and their x-rays are included as these are not always readily available on-line. More recently described species have such images available. Colour photographs and drawings show the appearance and variety of live fish. Live and freshly dead fish may vary quite markedly in colour pattern depending on age, season, sex, habitat, etc., and several images may be shown to demonstrate this. Some colour photographs are Iranian specimens while others are from elsewhere in the species range. Note that some photographs from outside Iranian waters may in the future represent a taxon not found in Iran, e.g., when a former synonymised subspecies restricted to the Caspian Sea is recognised as a species, or a wide-ranging taxon is found to contain several species of restricted distribution. However, the general shape and form are usually correct, at the time of writing the species is the same as the one found in Iran, and the photograph label indicated a non-Iranian source. Those sourced from Wikimedia Commons and cited literature may have more details at that source including descriptive information on the image, licensing and links to authors. Illustrations from Wikimedia Commons have the original file name (for easy location on Wikimedia as some file names are obscure; omitted if it is the same as the caption title such as a species name; in English if the original was in Farsi but nevertheless accessible by search; shortened in rare cases where file name is very long, ending in …), the license abbreviation, any major modifications, and the author. Modifications were usually rotation to have the fish head on the left, cropping superfluous material, cleaning the background, lightening, sharpening, etc. Some illustrations did not have extensive locality data accompanying them and rivers, for example, may cross through more than one province and the locality cannot be given precisely. Locality data for older illustrations may be interpreted or expanded as names of places and countries have changed. Preserved specimens are sometimes shown and these are usually discoloured but show body form and also indicate the condition of some type material, varying from good to very poor.

Common names are given first in Farsi (but in Roman script) where known, and then from surrounding countries and then in English. Farsi script is not used to avoid egregious and amusing mistakes by me. Diacritical marks are not given for Farsi names; they would be of little help to those unfamiliar with Farsi and perhaps unnecessary to those who are. Needless to say, there are variant diacritical marking systems and, in any case, pronunciation varies throughout Iran. Obviously, many variant Farsi names in Roman script are different transliterations of the same name. Common names were collected at www.briancoad.com over many years and a variety of sources through personal communications with Iranian colleagues. Recent sources for Farsi common names are Jouladeh-Roudbar *et al*. (2016, 2020). Not all fishes have Farsi or even English common names, although some have been contrived from the scientific name or the type

locality but are not true common names in general usage by non-scientists but "book names". An English translation is given wherever possible but some names have unknown origins and meanings. Other common names are also given, mostly those in use in the neighbouring countries Azerbaijan, Iraq, Pakistan, Russia (and former U.S.S.R.), Turkey and Turkmenistan, and also in English, but without being exhaustive. The orthography of Turkish names is not always accurate when given in English language publications, even by Turkish authors, and some attempt at consistency has been made. Esmaeili *et al*. (2018) was a source for some English common names (and presumably these may also be used in Farsi), others are in common use in Europe or are derived from European names, and some have a particular cited source. FishBase (www.fishbase.org/search.php) carries various common names of species. Afghan names are usually in Dari or Afghan Persian and therefore the same or very similar to those in Iran. Mikaili and Shayegh (2011) gave etymology of common and scientific names of fishes found in the Tigris-Euphrates basin. The Arabic words therein are given here in Roman script without accents. Names are usually given alphabetically, although some major common names in widespread use will lead the list. The same common name may be used for more than one species.

Systematics covers the history of the name, synonyms, a brief review of taxonomic opinions and research, and the museum location of type material. The scientific names of fishes may change as understanding of relationships evolves and can be tracked in the various works initially authored by W. N. Eschmeyer (see **Bibliography**). These appeared first in a published form and then as an online version, constantly revised as understanding of publication dates, synonymies, species distinction, authorship and other taxonomic factors change. The online version is referred to as *Catalog of Fishes* in this text. Species other than cyprinoids are referred to by the name appearing in the literature cited for clarity, followed by any major change in name after the *Catalog of Fishes*. Many old types of fishes from Iran, or from Iraq and Syria and found in Iran, described by J. J. Heckel (see **Bibliography**), are deposited in the Naturhistorisches Museum Wien (Vienna) (NMW). These often comprise a number of syntypes for each species with some material dispersed to other museums, and with websites, catalogues, labels and published sources somewhat at conflict as to which specimens are types. Generally, this has no nomenclatural significance and there is adequate material to establish species names and characters. Initially, data on type and other material in collections was garnered from catalogues and jar labels examined in the museum.



GROUP/GROUPE C 22 | N° de/CATALOGUE/No. ~~NMC~~ CMNFI 1977-0510 | N° de/SPÉCIMENS/No. 30 of 168 | STATUT du/TYPE/STATUS PARATYPES

SP. Alburnoides ganati

LOCAL. IRAN. Fars: at source and along stream of a ganat at Naqsh-e Rostam, Pulvar River system 29°59'30"N, 52°54'00"E

COLLECT Brian W. Coad, Sylvie Coad, John M. Gunn

DATE 6 October 1976

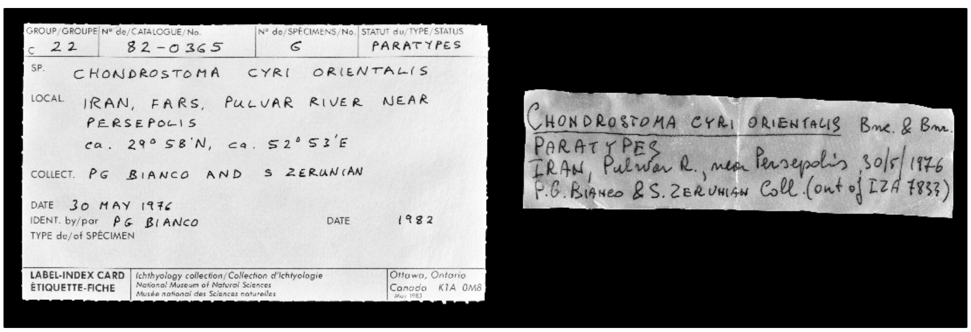
IDENT. by/par Brian W. Coad DATE June 2009

~~TYPE de/of~~ SPÉCIMEN

BWC 76-101

LABEL-INDEX CARD ÉTIQUETTE-FICHE | Ichthyology collection/Collection d'Ichtyologie National Museum of Natural Sciences Musée national des Sciences naturelles | Ottawa, Ontario Canada K1P 6P4 July 1989

Canadian Museum of Nature jar label, Bronwyn Jackson @ Canadian Museum of Nature.



GROUP/GROUPE C 22 | N° de/CATALOGUE/No. 82-0365 | N° de/SPÉCIMENS/No. 6 | STATUT du/TYPE/STATUS PARATYPES

SP. CHONDROSTOMA CYRI ORIENTALIS

LOCAL. IRAN, FARS, PULVAR RIVER NEAR PERSEPOLIS ca. 29° 58'N, ca. 52° 53'E

COLLECT. PG BIANCO AND S ZERUNIAN

DATE 30 MAY 1976

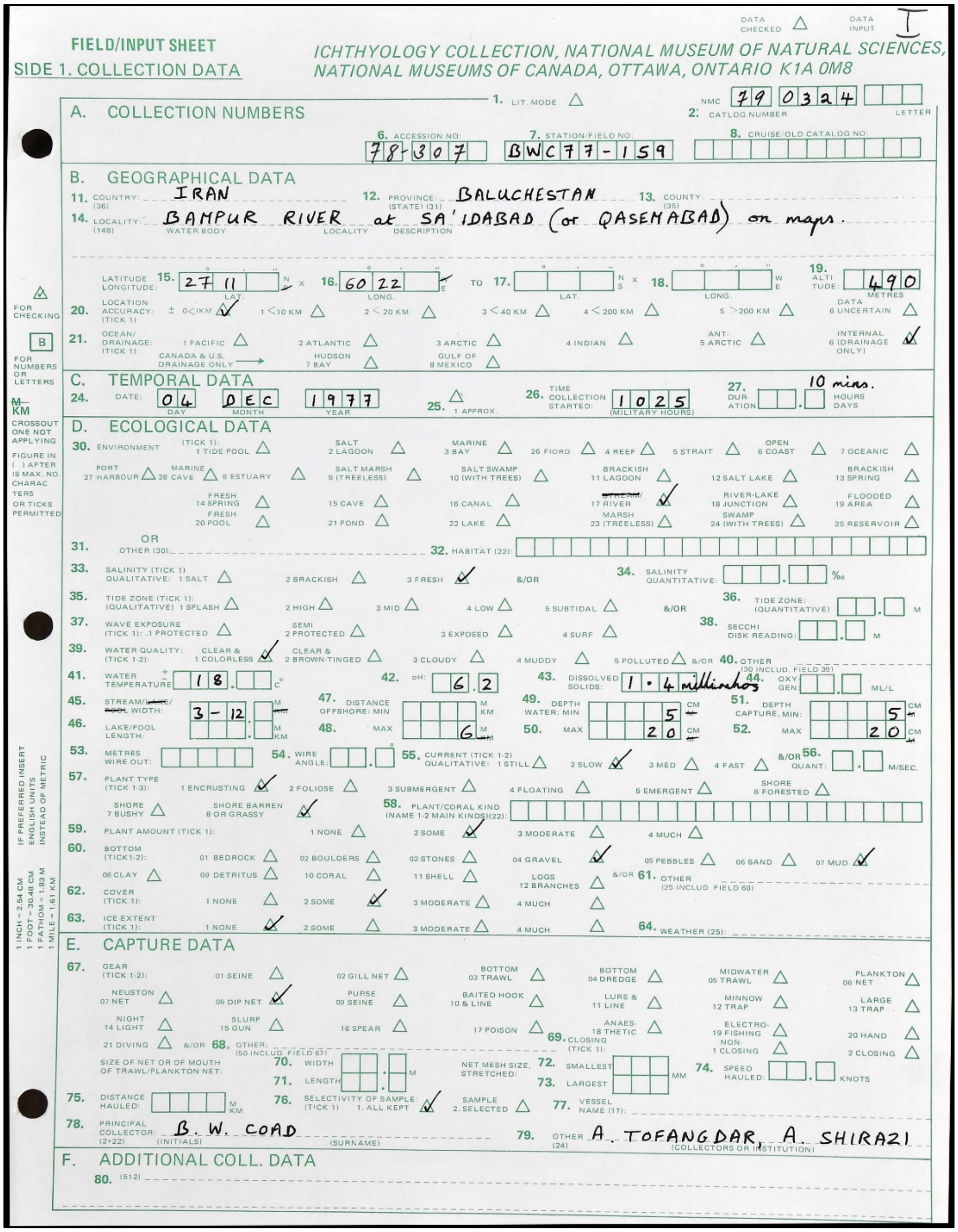
IDENT. by/par PG BIANCO DATE 1982

TYPE de/of SPÉCIMEN

LABEL-INDEX CARD ÉTIQUETTE-FICHE | Ichthyology collection/Collection d'Ichtyologie National Museum of Natural Sciences Musée national des Sciences naturelles | Ottawa, Ontario Canada K1A 0M8

CHONDROSTOMA CYRI ORIENTALIS Bnc. & Bnc.
PARATYPES
IRAN, Pulvar R., near Persepolis 30/5/1976
P.G. Bianco & S. Zerunian Coll. (out of IZA 7833)

Canadian Museum of Nature jar label and original collection label,
Bronwyn Jackson @ Canadian Museum of Nature.



DATA CHECKED △ DATA INPUT I

FIELD/INPUT SHEET
SIDE 1. COLLECTION DATA

ICHTHYOLOGY COLLECTION, NATIONAL MUSEUM OF NATURAL SCIENCES, NATIONAL MUSEUMS OF CANADA, OTTAWA, ONTARIO K1A 0M8

A. COLLECTION NUMBERS
1. LIT. MODE △ 2. CATLOG NUMBER NMC 79 0324 LETTER
6. ACCESSION NO: 78-307 7. STATION/FIELD NO: BWC77-159 8. CRUISE/OLD CATALOG NO:

B. GEOGRAPHICAL DATA
11. COUNTRY: IRAN 12. PROVINCE (STATE): BALUCHESTAN 13. COUNTY:
14. LOCALITY: BAMPUR RIVER at SA'IDABAD (or QASEMABAD) on maps.
15. LATITUDE: 27 11 N 16. LONGITUDE: 60 22 E TO 17. 18. 19. ALTITUDE: 490 METRES
20. LOCATION ACCURACY: ± 0<1KM ✓
21. OCEAN/DRAINAGE: INTERNAL DRAINAGE ONLY ✓

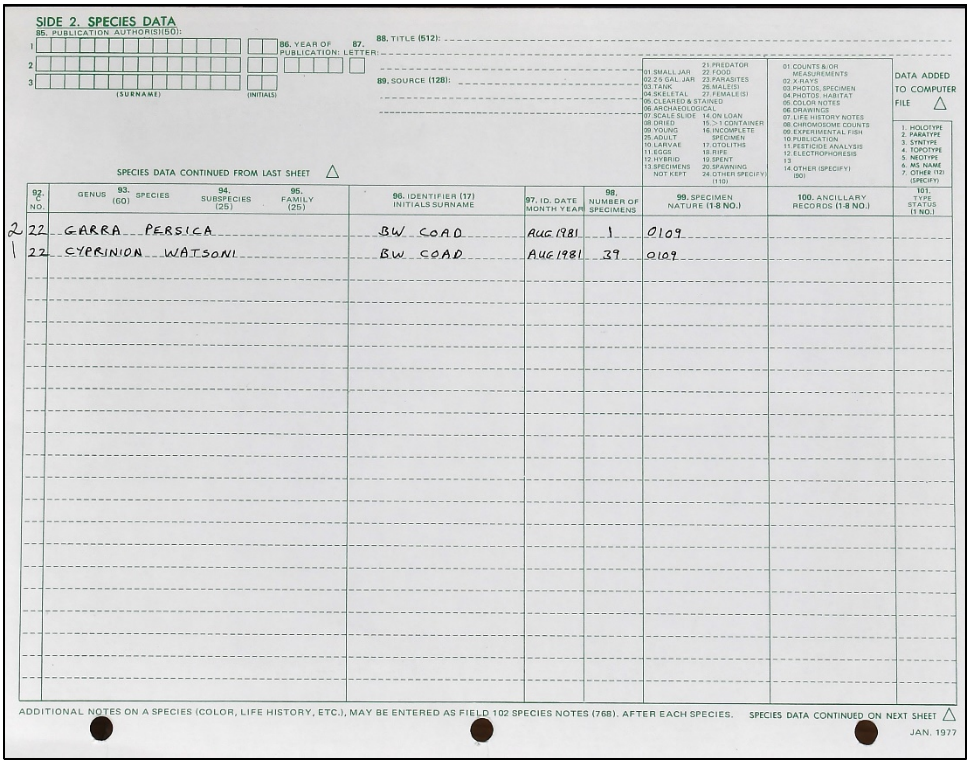
C. TEMPORAL DATA
24. DATE: 04 DEC 1977 25. APPROX. 26. TIME COLLECTION STARTED: 1025 (MILITARY HOURS) 27. DURATION: 10 mins.

D. ECOLOGICAL DATA
30. ENVIRONMENT: 17 RIVER ✓
33. SALINITY QUALITATIVE: 3 FRESH ✓
39. WATER QUALITY: 1 CLEAR & COLORLESS ✓
41. WATER TEMPERATURE: 18 °C 42. pH: 6.2 43. DISSOLVED SOLIDS: 1·4 millimhos 44. OXYGEN:
45. STREAM WIDTH: 3-12 M
48. DISTANCE OFFSHORE MAX: 6 M
49. DEPTH WATER MIN: 5 CM 50. MAX: 20 CM
51. DEPTH CAPTURE MIN: 5 CM 52. MAX: 20 CM
55. CURRENT QUALITATIVE: 2 SLOW ✓
57. PLANT TYPE: 1 ENCRUSTING ✓ 8 SHORE BARREN OR GRASSY ✓
59. PLANT AMOUNT: 2 SOME ✓
60. BOTTOM: 04 GRAVEL ✓ 07 MUD ✓
62. COVER: 2 SOME ✓
63. ICE EXTENT: 1 NONE ✓
64. WEATHER:

E. CAPTURE DATA
67. GEAR: 08 DIP NET ✓
76. SELECTIVITY OF SAMPLE: 1. ALL KEPT ✓
78. PRINCIPAL COLLECTOR: B. W. COAD
79. OTHER: A. TOFANGDAR, A. SHIRAZI

F. ADDITIONAL COLL. DATA
80.

Field/Input sheet for recording collections and computer input,
National Museum of Natural Sciences (NMC), now Canadian Musuem of Nature,
Brian W. Coad @ Canadian Museum of Nature.



SIDE 2. SPECIES DATA
85. PUBLICATION AUTHOR(S)(50):
1
2
3
(SURNAME) (INITIALS)
86. YEAR OF PUBLICATION: 87. LETTER:
88. TITLE (512):
89. SOURCE (128):
01. SMALL JAR 02. 2.5 GAL. JAR 03. TANK 04. SKELETAL 05. CLEARED & STAINED 06. ARCHAEOLOGICAL 07. SCALE SLIDE 08. DRIED 09. YOUNG 25. ADULT 10. LARVAE 11. EGGS 12. HYBRID 13. SPECIMENS NOT KEPT 14. ON LOAN 15. > 1 CONTAINER 16. INCOMPLETE SPECIMEN 17. OTOLITHS 18. RIPE 19. SPENT 20. SPAWNING 21. PREDATOR 22. FOOD 23. PARASITES 26. MALE(S) 27. FEMALE(S) 24. OTHER SPECIFY) (110)
01. COUNTS &/OR MEASUREMENTS 02. X-RAYS 03. PHOTOS, SPECIMEN 04. PHOTOS, HABITAT 05. COLOR NOTES 06. DRAWINGS 07. LIFE HISTORY NOTES 08. CHROMOSOME COUNTS 09. EXPERIMENTAL FISH 10. PUBLICATION 11. PESTICIDE ANALYSIS 12. ELECTROPHORESIS 13 14. OTHER (SPECIFY) (90)
DATA ADDED TO COMPUTER FILE △
1. HOLOTYPE 2. PARATYPE 3. SYNTYPE 4. TOPOTYPE 5. NEOTYPE 6. MS NAME 7. OTHER (12) (SPECIFY)
SPECIES DATA CONTINUED FROM LAST SHEET △

| | 92. C NO. | GENUS 93. (60) SPECIES | 94. SUBSPECIES (25) | 95. FAMILY (25) | 96. IDENTIFIER (17) INITIALS SURNAME | 97. ID. DATE MONTH YEAR | 98. NUMBER OF SPECIMENS | 99. SPECIMEN NATURE (1-8 NO.) | 100. ANCILLARY RECORDS (1-8 NO.) | 101. TYPE STATUS (1 NO.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 22 | GARRA PERSICA | | | BW COAD | AUG 1981 | 1 | 0109 | | |
| 1 | 22 | CYPRINION WATSONI | | | BW COAD | AUG 1981 | 39 | 0109 | | |

ADDITIONAL NOTES ON A SPECIES (COLOR, LIFE HISTORY, ETC.), MAY BE ENTERED AS FIELD 102 SPECIES NOTES (768). AFTER EACH SPECIES. SPECIES DATA CONTINUED ON NEXT SHEET △
JAN. 1977

Field/Input sheet reverse side, Brian W. Coad @ Canadian Museum of Nature.

Increasingly, this information is available on-line and is constantly corrected and updated and the relevant museum database should be consulted for these ongoing changes. Photographs and line drawings of type material where available are shown along with x-rays, principally from museums at London and Vienna (Wien). Captions for these figures use the original scientific name; the genus has often been changed subsequently and the ending of the trivial or species name may change too to agree with the gender of the genus. This section also contains genetic and DNA analyses of populations which may have taxonomic significance or may refer to stocks and have implications for fisheries and biodiversity management. Ghelichpour (2018) reviewed the application of microsatellite and mtDNA markers in the investigation of fish population genetics in Iran.

Key characters serve to separate the species from related species, usually within the same genus, by highlighting important features. The **Keys** should be consulted for an alternate method of identifying a specimen at hand. Some species are clearly defined and identifiable at a glance, others require some care to identify but are separable on external and/or accessible internal morphology, others are identifiable by a combination of characters which may leave some individual specimens of uncertain attribution, and some species are validly defined principally by molecular characters which are of no utility in the field or with preserved material. Some taxa are still under study or require more extensive studies to finalise their distinction (or not) from related species. More species may be discovered or some recognised species may be synonymised.

Morphology serves to describe the species. Morphometric characters are not usually given as measurement ranges or means here since they vary with size, sex and locality and are not absolute characters easily used in identification and characterisation of the species. Vajargah and Hedayati (2015) using Iranian *Cyprinus carpio* specimens noted shrinkage in morphological

characteristics of formalin-preserved fish, and presumably different preservation methods may yield variations in morphology that are not taxonomically valid. Morphological characters vary when a suite of sizes and both sexes are examined within a species. Fish that grow to a large size, in particular, show evident morphological variations between young and old fish. Characters that vary within a species include, e.g., the dorsal fin origin can be over, in front of or behind the level of the pelvic fin origin, a nuchal hump may develop especially in larger fish, barbel length varies with fish size and between fish of the same size, eye size varies with growth, the anal fin may reach back to the caudal fin base or not, the pectoral fin may reach back to the pelvic fin origin or not, the pelvic fin may extend back to the anus or not (paired fins are often longer in males), the caudal fin lower lobe is often larger than the upper lobe presumably helping to depress the head for bottom feeding, etc. Fish isolated in small pools may have a contracted abdomen through emaciation and loss of muscle mass. Descriptions based on only a few specimens can be misleading. Ideally morphometric characters should include at least 50 fish of each sex, locality and major size range - this is seldom if ever achieved. Various Iranian morphometric studies within a species show clear variation between populations for several characters and these are documented in the **Systematics** section. Meristic or countable characters are more definitive and include fin rays, scales, gill rakers, pharyngeal teeth and vertebrae. The methods of counting are given in **Material and methods**. Other characters that may be cited include presence and number of barbels, mouth shape and position, presence of a mental or chin disc, some generalised body shape descriptions, extent and shape of the lateral line, details of scale morphology, ventral or dorsal scaled or scaleless keels, chromosome number, etc.

Sexual dimorphism in cyprinoids is often evident as breeding or nuptial tubercles on the head, body and fins, best developed in males. Even small fish may develop tubercles but they are best seen on older fish. There may be variation between individuals and localities but this was not explored from lack of material. Since development of tubercles each spawning season is a gradual process, ideally only “high” (fully-developed) males would be compared but often the available material does not permit this. Closely-related fish will have similar tubercle patterns but fish from different genera will be quite distinct. Meristic characters do not usually vary with sex but morphometric variation is common. Pectoral and pelvic fins are often longer in males, and females with eggs will have a distended abdomen, for example.

Colour is based on observations of live fish in the field and on colour photographs. Colour varies with habitat, age, sex and spawning condition. Fish in qanats are often pale and fish in heavy vegetation may be quite dark.

Size is given in standard length, fork length or total length. Wherever type of length is not specified, the length measured was not stated. The length is for the species over its total distribution which may include fishes outside Iran. Length serves to give an estimate of the size of the species as most cyprinoids are quite small, some are of medium size, and some attain very large sizes, a distinctive feature. Fishes exhibit determinate growth in short-lived species of warmer regions and indeterminate growth in long-lived species of colder regions. Fishes showing indeterminate growth grow rapidly when young and continue to grow after reaching adulthood, although at a slower pace. A fixed maximum size does not exist.

Distribution of the species world-wide is briefly summarised. Distribution in Iran is based on literature sources (several studies may replicate a locality and not all are cited), museum collections (cited in the text where a recognisable river or other water body is named, but see also the **Sources** section), sight records of easily recognised species, and a database and generated maps used in Mostafavi *et al*. (2014, 2015, 2015) large parts of which are from my

records. A few records are from the GenBank database (https://www.ncbi.nlm.nih.gov/genbank/) and these are easily accessible at that site, are not usually cited herein, and are often mentioned or duplicated in the literature. Note that some fish identifications in GenBank are incorrect and localities can be vague. Distributions are given alphabetically by drainage basins (Bejestan, Caspian Sea, Dasht-e Kavir, Dasht-e Lut, Esfahan, Hamun-e Jaz Murian, Hamun-e Mashkid, Hari River, Hormuz, Kerman-Na'in, Kor River, Lake Maharlu, Lake Urmia, Makran, Namak Lake, Persis (formerly Gulf), Sirjan, Sistan, Tigris River). River names and other water bodies are each listed alphabetically with rivers usually separated from dams and marshes. Localities for some material are obscure, the transliteration through Farsi to Russian to English, for example, accounting for some of this. Older names have been given modern versions where determined or suspected and minor spellings changes (e.g., Araks River becomes Aras River). Some works may cite a locality in quite vague terms, e.g., a collection from a named river taken during the work of *The Turko-Persian Demarcation Commission* and cited in Berg (1949) may not specify a country, possibly because the country of the collection site was yet to be determined - the Iranian version of the river name is given (rather than the Iraqi Arabic or Turkish). The number of rivers and other localities cited under Distribution provide an insight into how common, or commonly caught, a species is. Some species appear to be quite rare naturally although collection methods and species recognition may play a part.

Zoogeography covers the origins and relationships of the species. It may be summarised in the description of the genus and is also covered in part in the introduction to the Carps.

Habitats in Iran comprise rivers, streams, lakes, dams, lagoons, ponds, marshes, springs, qanats, and brackish environments.

Dams are also referred to as reservoirs or dam lakes in the literature and here, all referring to water held back by the actual dam. Studies on environmental impacts of dams are mentioned below in some descriptions of the drainage basins. Pazoki *et al*. (2015), for example, described the case of the Jooban Dam in the upper Iranian Tigris River basin. Heydari *et al*. (2013) reviewed the environmental impact of large dams in Iran and Yazdandoost (2016) reviewed water balance and dam building. Noori *et al*. (2018) described temporal and depth variation of water quality from thermal stratification in the Karkheh Dam, and this presumably affects cyprinoid fishes. Dams form important habitats for fishes, including native and exotic cyprinoids. Mirzajani *et al*. (2020) studied nine small dams or reservoirs located in northwest Iran in two provinces: East Azarbayjan (Alkhalaj, Arasbaran and Ardalan) and Zanjan (Golabar, Khandaghloo, Mirzakhanloo, Shovier, Taham and Todebin). Prediction of fish productivity was calculated based on phytoplankton biomass (using chlorophyll a concentration in water). A eutrophication trend was very fast in these reservoirs because of high nutrient input from aquaculture activities. The use of fertilisers and large amounts of food for aquaculture and expansion of exotic species reduced the natural fisheries potential. *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *H. nobilis* have been released in most of the reservoirs, and rainbow trout (*Oncorhynchus mykiss*) were also reared in cages in a few reservoirs. Non-commercial exotic species were also inadvertently released such as *Carassius auratus*, *C. gibelio*, *Hemiculter leucisculus* and *Pseudorasbora parva* (see Coad (2019b) for the latter species). This is typical of many reservoirs across Iran where there is an emphasis on food production. Native species in northwest Iran such as *Capoeta capoeta* (= C. *razii*), *Rutilus frisii* (= *R. kutum*) and *Squalius orientalis* (= *S. turcicus*) have drastically decreased. The authors recommended maintenance of water quality and investigation of native species to preserve sustainable fisheries activities in these reservoirs.

Lagoons are found along the Caspian Sea shore, the most famous being the Anzali Talab. A lagoon is strictly a shallow pond or elongate channel separated from the open ocean by a sand bar or reef, or by a narrow outlet, with little or no freshwater input (the Anzali Talab is separated from the Caspian Sea by a narrow outlet but does have extensive freshwater input from inflowing rivers). The terms lagoon, marsh, swamp and wetland are often used interchangeably in Iran and in this text. Some may even be referred to as a lake, pond or spring, referring to the open water or source of the water supply. Brackish environments include waters entering salt lakes, saline streams such as those near salt domes in southern Iran, and the Caspian Sea which is one-third seawater and less near river mouths. In some cases, a particular cyprinoid species is the only one found in that habitat, especially springs and qanats in desert areas. Some habitats have a wide range of co-occurring species such as in the Caspian Sea and Tigris River basins where conditions are varied, habitat complexity is high and zoogeographical history is diverse. Some collection habitat data is given, especially from type localities and from species with restricted distributions as there may be no other information available. There are few detailed descriptions of habitat requirements for individual species although general descriptions and photographs of particular habitats are found below in the section on the **Environment**. Photographs of habitats also occur in various species descriptions. Habitats for widely distributed fishes in Iran are quite varied in dimensions and types, and through the year in fishery pressure, water levels and dimensions, temperature regimes, chemistry, insolation, pollution, bottom types, aquatic and terrestrial vegetation, food availability, etc. Spot data gives some information but is of restricted utility compared to a full and diverse study of habitat requirements. Most fish seem to tolerate a wide range in temperature, less than 10°C to over 30°C. Water quality varies widely both by season and habitat type naturally and by human influence. Drought is often a significant factor. Many waters are polluted, at least in part, from domestic, industrial and agricultural waste. Many habitats are exposed to the sun and have little shelter for fishes, exceptions being forested areas along the Caspian shore, marsh areas with extensive reed beds such as in Sistan and Khuzestan and inside qanats. Aquatic vegetation is often encrusting, particularly in the shallower streams and many species are scrapers of this food source with adapted mouths. Fish occur in both shallow and deep waters of large and small water bodies, over a wide variety of bottoms even in the same river, and in still to fast water.

Age and growth information may be cursory. Many species are poorly known and their biology has not been studied, especially within Iran, although this is rapidly changing. Some information is available for species shared with Turkey and Iraq and I have tried to incorporate this literature as being less well known or accessible. Some Caspian Sea basin species are shared with Europe and the former U.S.S.R., are comparatively well-known and have an extensive literature, often summarised in books, bibliographies and synopses. It is not known in many cases if their biology in Iran is similar. Iranian populations were often referred, variably by authors, to distinct subspecies and occur at the southern limit of the species range. Subspecies of past literature are now often elevated to species with a more restricted distribution and presumably a distinct or somewhat distinct biology. Only a brief, summary account of their biology is therefore given from synoptic literature sources. Biological information generally is a brief summary of literature and readers should consult the original papers for more details.

Some anecdotal biological information is added from my field collections where spawning individuals were noted or gut contents examined superficially.

The Age and growth section includes data on maximum age, age at maturity (sometimes given in the Reproduction section), most numerous age group(s), sex ratio, the length-weight

relationship, condition factor, and the von Bertalanffy growth equation or parameters. There are various books and papers explicating age and growth in fishes, e.g., Ricker (1975) - available on-line and only a brief summary is given below.

The length-weight relationship is expressed as $W = aL^{b}$, where W is weight in grammes, L is length (usually total length, and sometimes given as TL in the formula and see below for other lengths), a is the intercept, and *b* is the slope. *b* values usually range from 2.5 to 3.5. This equation serves to convert lengths, more easily obtainable, to weights. The *b* value indicates isometric growth when the value is 3, and is positively or negatively allometric when higher or lower than 3. At values greater than 3, fish become fatter or have a greater girth as they increase in length, while below 3 they are more streamlined. This relationship is sometimes expressed as a logarithm transformation, $\mathrm{Log}W = a + b\mathrm{Log}L$. The value of this relationship varies with sample size and with separation of samples by sex and size. Some samples in the literature are combined from several localities. Accordingly, the data presented must be assessed bearing these factors in mind. The length-weight parameters can also be influenced by such factors as diet, diet quality, availability of food, feeding intensity, gut fullness, degree of muscular development, fat reserves, habitat, health, disease and parasite loads, maturity status, preservation techniques, season, water temperature, fishing methods (type of gear used to capture the fish as this may be selective), and duration of the study (one time sample or monthly for a year or more). These factors also affect the condition factor.

The condition factor or Fulton's condition factor (K) is derived from $K = 100W/L^3$, where W is weight in grammes and L is total (TL), fork (FL) or standard length (SL) in centimetres (length chosen is not always stated). The condition factor reflects the interaction between biotic and abiotic factors in the physiological condition of fishes. Heavier fishes of a given length are in better condition, and the factor is also used as an index of growth and feeding intensity. Condition factors equal to or greater than 1.0 indicate a good level of feeding and good environmental conditions. The relative condition factor compensates for changes in form or condition with an increase in length and is derived from $K_n = W/aL^{b}$ where W is weight (g), L is length as above and *a* and *b* are the exponential form of the intercept and slope of the logarithmic length-weight equation. Values higher than 1 indicate the well-being of the fish is good. Most works cited herein give the condition factor (K).

The von Bertalanffy growth equation or parameters are used to describe individual fish growth as a function of time. The abbreviations and symbols appear variously in the literature, parts being capitalised or lower case, subscript or superscript, in italics or not. Two biologically meaningful parameters are included: $L_\infty$, the average maximum length or asymptotic length, and K, the rate at which the fish approaches $L_\infty$. These two parameters are highly correlated with small species generally having higher values of K and large species generally having lower values of K. $L_\infty$ and K are variously given in italics or not, or with the infinity sign (∞) lower case or not. The growth equation is $L_t = L_\infty[1-e^{-K(t-t_0)}]$ where $L_t$ = is the total length at age t, $L_\infty$ = asymptotic length (mean length of a very old fish), K = the curvature parameter showing how fast a fish approaches its maximum value, and $t_0$ = the hypothetical age for $L_t = 0$. A short-lived species will have a high value of K and approach $L_\infty$ rapidly while other species have a low K and take a long time to reach $L_\infty$.

The growth performance index (phi or Φ) is $\log_{10}K + 2\log_{10}L_\infty$ where L and K are from the von Bertalanffy equation. Natural mortality (M) = deaths from all causes except man's fishing, including predation, senility, epidemics, pollution, etc. Fishing (F) mortality = fishing and natural mortality acting concurrently, F is equal to the instantaneous total mortality rate,

multiplied by the ratio of fishing deaths to all deaths. Total mortality (Z) = the instantaneous mortality rate (M and F are additive instantaneous rates that sum up to Z). The exploitation rate (E) is the ratio of fish caught to total mortality (= F/Z when fishing and natural mortality take place concurrently).

Age may be given in absolute months or years but is often stated in the form $0^+$, $1^+$, etc., meaning fish from birth to less than one year of age and fish from one year of age to less than two years of age, etc. Cyprinoid fishes can be aged by growth rings on scales, otoliths and the operculum bone.

The Reproduction section covers maximum egg size, spawning migrations, spawning time or season, spawning sites, behaviour, gonadosomatic index (gonad weight expressed as a percentage of whole body weight and used to describe the gonad maturation cycle), absolute fecundity (total number of eggs in mature females, which tend to increase with the age and size of the fish both within a species and between species), and relative fecundity (eggs per gramme body weight). Age at maturity may be given here or in the section on Age and growth.

The Food section covers dietary items almost always determined from gut contents. The food of juveniles and adults may differ. Feeding habits can often be deduced from morphology. Fishes with an arched and ventral mouth, horny jaw edge, elongate gut and black peritoneum are feeders on detritus and aufwuchs scraped from rocks. Most fishes with a simple, s-shaped gut feed on invertebrates such as crustaceans and aquatic insect larvae. A few fish with molar pharyngeal teeth have a diet of molluscs whose shells are crushed by the heavy teeth. Some fish are piscivorous and have an appropriate jaw shape and streamlined appearance suitable for catching and holding their fish prey. Fish with elongate and numerous fine gill rakers filter phytoplankton or zooplankton from the water column. Very few fish feed on macrophytes (large plants).

The Parasites and predators section briefly lists the parasites recorded from the species and the locality of the study. Readers should refer to the literature cited for further details such as prevalence and intensity of infection. Some parasites are zoonotic parasites or zoonoses, communicable from fish to humans. Changes in fish taxonomy make the identity of some species uncertain and assumptions have been made, and so noted, based on distribution. Masoumian and Hosaini (2015) described the Iranian Fish Parasite Data Base at Tehran University. Soltani (2021) listed sources of diseases in Iranian fish namely import of ornamental fishes, entry of wild aquatic species carrying pathogens through border rivers, import of pathogens by researchers/research centers with research objectives, experiments on native species using imported pathogens, repeated use of lethal pathogens by inexperienced or unqualified people for laboratory studies, and bioterrorism. Predators are listed where specifically recorded in the literature. Most, smaller cyprinoids are prey for other fishes, birds (see Behrouzirad (2005, 2007), for example), mammals, and even the mugger, a crocodile, in Iran. The Caspian seal, *Pusa caspica*, is a significant predator on fishes in the Caspian Sea.

Caspian seals, *Pusa caspica*, Gilan, Bandar Anzali Shilat, 5 June 1978, Brian W. Coad.

Economic importance gives details of the commercial, food, sport and ethnological importance of the species. Karizaki (2016) gave details of ethnic and traditional foods in Iran involving fish. These include chelow mahi (pilaf-fish) using rice, fish, onion, turmeric and saffron, lakh lakh using rice, fish, garlic, onion, turmeric, pepper, coriander, dill, fenugreek and tamarind, polow bandari (bandari-pilaf) using rice, capsicum, garlic, onion, green pea, canned fish, coriander and pepper, and tahchin mahi using rice, fish, yogurt, egg yolk, dill, coriander, butter and saffron. The use of these in ceremonies and as medicine are also discussed.

The Experimental studies section covers work in the field and laboratory on aspects of pollution, reproduction, aquaculture, nutrition and the general use of the fish species as a test organism. There is an evident and marked increase in such studies over time and the volume of information is often summarised in a single sentence for each study - most studies are readily available online where subtleties and details can be read. Some species, e.g., *Cyprinus carpio*, have an extensive literature in these fields outside Iran but only the Iranian works are cited here, as with other species herein. Study coverage is reasonably thorough without being total and gives a good overview of these works in Iran. Iranian fishes have been examined for their reaction to a number of chemical compounds such as herbicides, commercial hormone preparations, heavy metals, insecticides, prebiotics, probiotics, etc. The fish may be tested in the laboratory as an experimental animal or in the field as an indicator species or as a measure of environmental effects on the fish. One common measure of toxicity that appears in abbreviate form is the $LC_{50}$ 96 h, the lethal concentration killing 50% of the fish over 96 hours (and variants in percent killed over time). Commercial compounds (herbicides, hormone preparations, insecticides, prebiotics, probiotics, etc.) may or may not be capitalised in the literature while antibiotics, drugs, heavy metals, plants and vitamins generally are not. They are all left as lower case here. Further information on these elements and compounds can easily be Googled and are not detailed here. The text in this section is arranged as follows:- 1) *Pollution* including heavy metals, herbicides, pesticides, microplastics, etc., and see a review of bioaccumulation of heavy metals in Iranian fish by Sheikhzadeh and Hamidian (2021) and briefly microplastics by Pourasadi (2021), 2) *Diet* as part of fish farming including food, prebiotics (typically nondigestible fibres that induce the growth or activity of beneficial bacteria), probiotics (live microorganisms said to improve or

restore the gut flora) (see Dawoud and Koshio (2016) and Akrami *et al*. (2018) who reviewed recent advances in the role of prebiotics and probiotics in carp aquaculture), etc., separated from Aquaculture as dietary studies are extensive, 3) *Aquaculture* including broodstocks, stocking density, maturation stages, histology, ponds and tanks, etc., Hosseinzadeh Sahafi (2015) reviewing optimum management of warmwater fish farm stocking, capacity determination, growth rate and brood stock managements and harvesting in Iran and Tabrizi *et al*. (2017) the optimisation of the warmwater fish supply chain, 4) *Chemical composition and food safety* including nutritional quality and composition, shelf life, fish products, 5) *Disinfection and healing* including antifungal and antibacterial treatments, parasite baths, etc., 6) *Hormones and immunology* including spawning induction, immunostimulants, etc., 7) *Spermatology* including sperm quality, activity, cryopreservation, etc., Baradaran Noveiri and Hassanzadeh Saber (2018) giving methods of sperm quality assessment, 8) *Haematology* including biochemistry, dietary effects, etc., 9) *Stress* including diet, transport, environment, etc., 10) *Anaesthesia* including anaesthetics, slaughtering, etc. Necessarily there may be some overlap between these areas. Not all areas are found in species which have Experimental studies. Only those species, such as *Cyprinus carpio* and *Rutilus kutum* which have extensive studies, have the headings included in the text. Other species have their limited studies divided by paragraphs. Most papers are presented sequentially by year but a few studies, all at the same locality or by the same author on a single subject, may be grouped together. Many reports tend to address several factors (such as "growth performance, survival, body composition, stress resistance and some haematological parameters" to cite one paper) and so cannot be easily grouped by topic without excessive repetition.

Conservation details efforts or needs for the preservation of the species in its natural environment and applies mostly to native fish within Iran. Sometimes the only source of information is the IUCN (2015) and this is usually based on the whole species range with little or no information from Iranian populations. The IUCN Red List should be consulted for further data and for updates on status (https://newredlist.iucnredlist.org/).

Sources may reference a paper as a source for much of the information on that species. Material examined by me including type material, Iranian material and comparative material from other countries. The type material listed is that examined by me simply by catalogue number; the **Systematics** section lists all types in more detail. Collections are listed firstly by those from the Canadian Museum of Nature (CMNFI) and then alphabetically by other collection acronym. The Iranian and other comparative material are listed sequentially by catalogue number for easier location on the page rather than grouping by province or drainage basin. Latitude and longitude are given for localities wherever known and usually omit seconds. Many collections were made prior to a Geographic Information System (GIS) being available, there was a lack of good maps, and it was often difficult to establish where we were (on one trip we were lost for a whole day). Counts and measurements summarised in the Morphology section are based on both Iranian and comparative material and on literature sources. Counts for Iranian material are given separately. Occasionally the number of specimens examined for various characters may not be the same because structures were damaged or required dissection and damage to rare or loaned material. The Sources section should be considered with the Distribution section for Iranian localities of the species as some are not from named rivers or other water bodies. This data also serves as a rough measure of abundance and how common a given species is, at least within the limits of collecting equipment and habitat accessibility. Some species are regularly encountered when seining or electroshocking while others appear to be quite rare. Larger predatory

cyprinoids are less likely to be caught than smaller species feeding on aufwuchs as relative numbers and ease of capture differ. The data is presented in an abbreviated form with catalogue number (museum acronym and number - see *Catalog of Fishes* and Sabaj (2020) for explanation of acronyms although some Iranian private and local collections are explained in the text), number of specimens, standard length, locality and latitude/longitude where known. Note that the catalogue number may include a year but this is not necessarily the year the material was collected but when it was catalogued. The Natural History Museum, London has the old acronym BM(NH) for the former name British Museum (Natural History) and is now NHMUK in Sabaj (2020) and BMNH in the *Catalog of Fishes* so sources vary. The comment “no other locality data” indicates that the exact locality could not be determined, e.g., the specimens are from a named river but where on that river was not specified in the collection record. Occasionally species were observed but no material was retained (“not kept”) but serve to indicate distribution and abundance. Further information on the collections can be obtained from the holding institution (often now online). Major literature summaries on the species may be referenced here. Qanats and jubes as sampling localities are explained in the Habitats section below. Shilat is a term for the Iranian Fisheries Organisation or Fisheries Company in various incarnations, responsible for fisheries management and aquaculture. Particularly in the Caspian Sea, Shilat Posts are landing sites for fisheries and appear in the Sources.

The collection localities are given with the province but the limits of these have changed over time, e.g., Khorasan is now in three parts and older literature refers to the larger single province, and Mazandaran is now split into Mazandaran and Golestan with the same comment. The number and limits of provinces in north central Iran around Tehran have also changed too with several provinces formerly under just Markazi. Attempts have been made to modernise province names in **Sources** but citations of data from older papers retain the older provincial name. There are variant spellings of province names but these are usually obvious. Sistan and Baluchestan Province is usually referred to here in the text and **Sources** as Sistan (the hamuns or marshes and neighbouring areas) and Baluchestan (the southeast part of Iran to the south of Sistan), for convenience and clarity. Province names have been partly anglicised for clarity of use by non-Farsi speaking users, e.g., East Azarbayjan rather than Azarbayjan-e Sharqi. Azarbayjan refers to the Iranian provinces while Azerbaijan refers to the country to the north (and Azarbaijan is a variant spelling for the Iranian provinces). The map below summarises current provinces.


Provinces of Iran
(Map of Iran with province names and neighboring land, CC BY-SA 4.0, Ali Zifan).

Some local geographical and fish-related terms are explained in the text (and see below) for those unfamiliar with Farsi. Ichthyological terms are defined in the Dictionary of Ichthyology at www.briancoad.com.

A **Bibliography** (in Volume II) comprises books and papers referred to in the text and other relevant works, which form a good general basis for the serious student of Iranian cyprinoids. It should be noted that websites can change their content and correct errors - the information included here was that at the time of downloading.

## Materials and Methods

### Materials

The descriptions in this work are founded on original observations of material and a consideration of the literature. The sources of this material are various museums which house a scattering of Iranian species including in particular the Natural History Museum, London (formerly the British Museum (Natural History)), the Naturhistorisches Museum Wien, and the Zoological Institute, St. Petersburg which are depositories for older type material, but the bulk of the research has been based on four collections. The first major collection was made by V. D. Vladykov during 1961 and 1962 when he was an Inland Fisheries Biologist under the Expanded Programme of Technical Assistance of the Food and Agriculture Organization, UN. This

material was deposited in the National Museum of Natural Sciences, Ottawa (now the Canadian Museum of Nature) and consists mainly of specimens from the Caspian Sea basin. I was taken on as his Ph.D. student to work up this material in 1971, 50 years ago.

Professor Vadim D. Vladykov and Sylvie Pharand (shortly to be Coad) examining lampreys at Ottawa University, early August 1973, eponymous for *Esmaeilius vladykovi* (Aphaniidae) and *Glyptothorax silviae* (Sisoridae).

The second collection was made by employees of the Department of the Environment, Tehran, and N. B. Armantrout and R. J. Behnke. Half this collection was placed in the National Museum of Natural History, Tehran (Muze-ye Melli-ye Tarikh-e Tabi'i) and half was retained by R. J. Behnke and formed the basis of Saadati's (1977) thesis at Colorado State University, Fort Collins. This collection covered the whole of Iran except the Caspian and Sistan basins. Through the courtesy of Dr. Behnke, I was able to examine this material in Fort Collins and this material is now housed in the Canadian Museum of Nature. The Muze-ye Melli-ye Tarikh-e Tabi'i collection was small (examined in 1995; catalogue 2000) and not as diverse as the Fort Collins material. Oregon State University contained a third collection of fishes made by W. Kinunen, S. Bullock, R. RaLonde and P. Walczak, who were members of the Peace Corps in Iran (some of this collection was deposited at the Smithsonian Institution, Washington, which helped to fund the collection and transport of specimens). Dr. Carl Bond kindly loaned me much of this material for long periods. This collection was from all parts of Iran. The last collection, comprising the

bulk of the material, was made by me from 1976 to 1979 while I was teaching at Pahlavi (now Shiraz) University in Shiraz. This collection is housed in the Canadian Museum of Nature, Ottawa (formerly NMC, then CMN, now CMNFI), and covers all of Iran except the extreme northeast and northwest. Field trips were funded by the Research Council of Pahlavi University. Subsequently various Iranian colleagues have sent me specimens and two other collecting trips in 1995 and 2000 provided additional material and these too are incorporated in the present work. Principal among the collections by colleagues were those by Asghar Abdoli (then based in Golestan) and Nasser Najafpour and associates of the Iranian Fisheries Research Organisation (IFRO), Khuzestan. The holdings of cyprinoid fishes from Iran in the Canadian Museum of Nature comprise 1,834 species lots (jars). These collections together effectively cover all the major drainages of Iran and provided the best foundation yet assembled for a study on this ichthyofauna until the great expansion of collection and research by local scientists in the last two decades.

All material stored at the Canadian Museum of Nature, Ottawa was examined in either 45% isopropyl alcohol or in 70% ethanol. The Canadian Museum of Nature also stores extensive field records including slides, numerous data sheets on most species (counts and measurements including x-ray plates), an extensive literature base including translations from foreign languages, and comparative specimens and literature from other countries in Southwest Asia.

**Methods**

Various works give explanations of collecting methods for fishes including, for example, Coad (1995b), Neumann (2010), García-Melo *et al*. (2019) and Freyhof *et al*. (2020). Specimens collected by me in Iran were caught by any means that presented themselves. Gear used included seines of various lengths and mesh sizes (much repaired and patched!), gillnets of various stretch meshes (sometimes used as seines), cast-nets of several diameters (thrown skilfully by others and poorly by me), by hand, and by purchase from small boys and anglers using a variety of techniques (of angling on their part and of persuasion on mine to extract catches from their possession).

CMNFI 1979-0309, cast net catching *Capoeta saadii* and *Cyprinion watsoni*,
Kerman, Fahraj River at Azizabad, 30 November 1977, Brian W. Coad.

CMNFI 1979-0438, large dip-net catching *Alburnus chalcoides*, *Capoeta razii*
and *Vimba persa*, Gilan, Gholab Ghir River, 5 June 1978, Brian W. Coad.

The object was to sample any water body for all the kinds of habitat found there within the limitations of a hasty schedule and the available equipment. Most habitats were visited for less than one hour, but in the small springs and streams, which comprised the bulk of Iranian fresh waters outside the large rivers and lakes of Khuzestan and Sistan, this was more than adequate to catch a good and varied sample of most species. This was borne out by repeated visits of longer duration to certain localities near Shiraz. Pools and flowing sections were seined, gill-netted or cast-netted. Riffle areas were also attacked in this fashion or seines were used to block off

sections of riffle and upstream rocks disturbed by kicking to scare secretive species into the fixed net. In small streams a dip-net was placed downstream of individual rocks which were kicked over and the net scooped along the stream bed. Cast-nets proved particularly useful in rocky streams which had little open water. Draped over the rocks and only partly in the water, they nevertheless caught large and fast specimens which were unobtainable by seining. The available fishing gear was less effective on large rivers and on the Caspian Sea. Here boats, long gillnets and trawl gear would have been most useful. The collections are poor in inhabitants of the main current of large rivers and in the deepwater species of the Caspian Sea. Larger specimens in major water bodies undoubtedly evaded my nets with ease; some samples of larger individuals were available from other collections and by purchase from commercial fisheries.

Several criteria were used to select specimens for counts and measurements. Where few specimens were available, all were counted and measured. Where several hundred specimens were available selection was by size (usually larger fish; sometimes much smaller fish as well for comparison with adult values), by sex to ensure an adequate representation of males and females, and by locality where geographical variation was examined. Badly damaged or grossly deformed specimens were excluded but there was no (conscious) selection for “ideal” specimens.

Wherever a putative species was collected from more than one drainage basin and material diversity permitted, a comparison was made between the drainage basins. Students of Iranian fishes should note that the application of sufficient statistical “weight” will reveal differences between drainage basin samples and this is especially true of a desert and semi-desert country like Iran. Springs and streams may have been colonised by only a few founders. A small population sampled in the lower reaches of a stream may not have had any contact with conspecifics higher up in the stream for many generations. Conversely, several seasons of heavy rain may have afforded recent opportunities for contact and gene exchange. A one-time sample from a stream may therefore give a quite inaccurate picture of the character suite of that population. Whether any of the differences detected have systematic significance requires careful consideration. For example, Balletto and Spano (1977) described nine subspecies of *Garra tibanica* in the southwest of the Arabian Peninsula using principal components analysis. This has been termed “statistical overkill” by Alkahem and Behnke (1983). Also, Krupp (1983) has observed that samples of *Garra rufa* from the same locality collected in different years or seasons varied in several characters. Description of subspecies or species based on limited material requires a great deal of care therefore. The use of DNA evidence has helped alleviate this problem, revealing more diversity than previously thought, e.g., see such genera as *Capoeta* and *Garra* in Cyprinidae and *Alburnoides* in Leuciscidae. However, limited DNA data (often a single mitochondrial gene) may be misleading and a robust phylogenetic treatment would require sequence data from many more genes including nuclear ones. Liu *et al*. (2017) advocated multilocus DNA barcoding and evidently more refined work needs to be done to clarify species distinction and relationships.

Molecular taxonomy has developed greatly since this study of cyprinoids in Iran began. Such work often confirms species identity formed on morphology and reveals cryptic diversity. Where once wide-ranging species showing some variation were recognised, modern studies now reveal more putative species. Palandačić *et al*. (2017) gave an interesting review contrasting morphology and molecular data using the European leuciscid genus *Phoxinus* (not in Iran). They concluded that the use of molecular data, especially the single gene approach, for species delimitation may have pitfalls. Kiani *et al*. (2017) also noted that using only one gene has limitations and, to make robust inferences, it would be better to use other genes too. New Iranian

cyprinoid species based on a single gene and overlapping morphological characters used in combination may not be valid. Conversely, synonymy based on no difference in a single gene with overlapping morphological characters may not be valid. My approach has been to follow the latest separation into species and the latest synonymy with some exceptions notably in the genus *Alburnoides*, *q.v.*).

Rezvani Gilkolaei (2016) described the establishment of a gene bank for Iranian inland water fishes, and Pourgholam *et al*. (2017) for Caspian Sea bony fishes but this latter was limited among cyprinoids to *Barbus brachycephalus caspius* (= *Luciobarbus caspius*), *Rutilus frisii kutum* (= *R. kutum*) and *Rutilus rutilus caspius* (= *R. lacustris*) for preserving biodiversity and managing genetic risk of populations.

Also, based on my studies, small sample sizes used in new species descriptions may give a false view of morphological distinction - apparently discrete or minimally overlapping characters tend to merge when larger samples are examined, and when sexes, size ranges and localities are examined and compared separately. Other studies on Iranian cyprinoids documented in this book have shown morphological variation attributed to habitat or environmental differences (fast and slow water for example). The use of larger sample sizes from varied habitats, comparison of similar sized fish and the same sex, more genes, discrete morphological characters, and perhaps behavioural and ecological data, may be necessary to fully discriminate species. It may be expected that the current diversity of cyprinoids recognised in Iran will be modified when more exhaustive studies are undertaken.

There are various methods of measuring and counting anatomical features of fishes. The ones I have used are outlined below. They are based on Hubbs and Lagler (1958) and Trautman (1981). Some particular characters are outlined in papers by me in the **Bibliography**.

The method of counting fin rays differs from that in use in North America since unbranched and branched rays are counted separately. A “III,8” count in the European literature would be “9” in the system advocated by Hubbs and Lagler (1958), i.e., the soft ray count is increased by one to convert from the “European” to the “American” system. The bulk of the work on fishes of Southwest Asia follows the European system and I have adopted this methodology to facilitate comparisons, although eschewing Roman numerals.

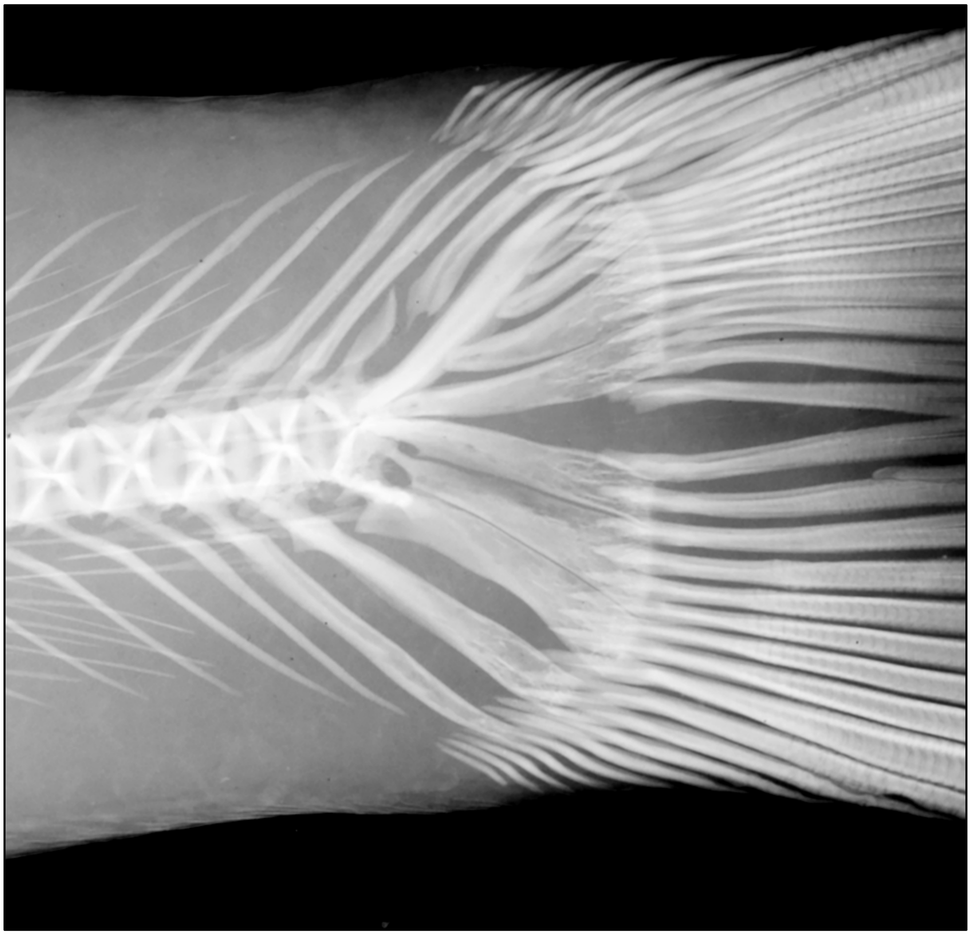
A) Meristic characters

In this book, scale counts, number of gill rakers and of vertebrae are usually expressed as ranges based on literature sources since frequency counts are rarely given. A separate section gives counts on Iranian fish examined by me followed by a frequency in parentheses. Fin ray counts often show strong modes, but citing the mode alone would be misleading. Pharyngeal tooth formula is often a modal value from the literature; loss of or incomplete development of major or minor row teeth is not uncommon, so counts may vary quite markedly.

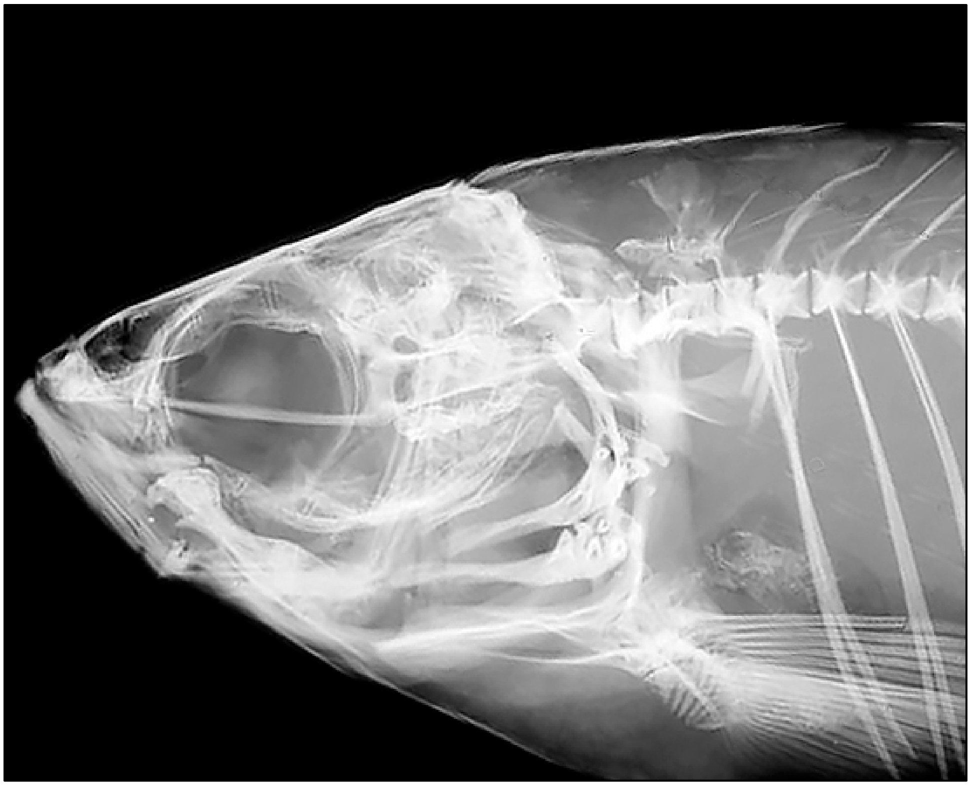
Scale counts and paired fin ray counts were made on the left side of each fish. In some instances, such as a badly deformed fin or where scales on the left were mostly missing, counts were made on the right. These instances were rare and restricted to species with low sample sizes.

Not all meristic characters had equal sample sizes; some material from other museums was not available for x-rays, large series of pharyngeal tooth counts was not often available because removal of arches damages specimens, some specimens were damaged in certain characters, time did not always permit all characters to be counted, some species are well-known and additional data from Iran is clearly a subset of widely gathered data, some species were examined in detail to address systematic problems, and so on.

1) Vertebrae
All vertebrae were counted including the hypural plate as one vertebra. The four Weberian vertebrae were included in the count. Almost all counts were made from radiographs.



Hypural plate of *Luciobarbus xanthopterus*, NMW54786, paralectotype, with four vertebrae anterior to it, Naturhistorisches Museum Wien.


Head of lectotype of *Alburnus doriae*, MZUT P1110 or N.720, showing four Weberian vertebrae followed by the fifth vertebra with ribs ventrally and first neural spine dorsally. Pharyngeal teeth are visible between the anteriormost vertebra and the pectoral fins, Brian W. Coad.

2) Gill rakers

All rakers on the first gill arch were counted (see **Key to Genera of Cyprinidae** below for figure). A lower limb count in the literature includes any raker at the angle of the upper and lower limbs. It was not always clear if literature counts were of the lower arch only. Wide ranges in literature counts may indicate both total and lower arm counts are conflated but some species examined by me do have a surprisingly wide range in counts. Gill raker counts presented something of a problem when comparing specimens of disparate sizes. The smaller fish often had very small rakers at each end of the arch. These were easily missed or torn off when cleaning a debris-encrusted arch. Removal of arches for a more careful examination may also damage or destroy the finer rakers which are intimately associated with the tissues adjacent to the arches. Alizarin preparations can be of assistance, but the finer rakers may have no bony content and thereby be omitted. Counts of juvenile fish may therefore give lower values than counts for larger fish, whether this is due to an increase in gill raker number with age or because rakers are easier to count in larger fish. This kind of variation is only critical where this character is being used in species identification or in analyses meant to define and relate species.

3) Pharyngeal teeth

The teeth of the modified fifth gill arch in Cyprinoidei were counted in each row and given as a formula from left to right (see **Key to Genera of Cyprinidae** below for figure). A count of 2,5-4,2 consists of two teeth in both the outer left and outer right rows, five teeth in the inner left row and four teeth in the inner right row. Pharyngeal teeth rows in Iranian cyprinoids varied from one to three on each side. In certain cases, it was evident from the presence of a socket that a tooth

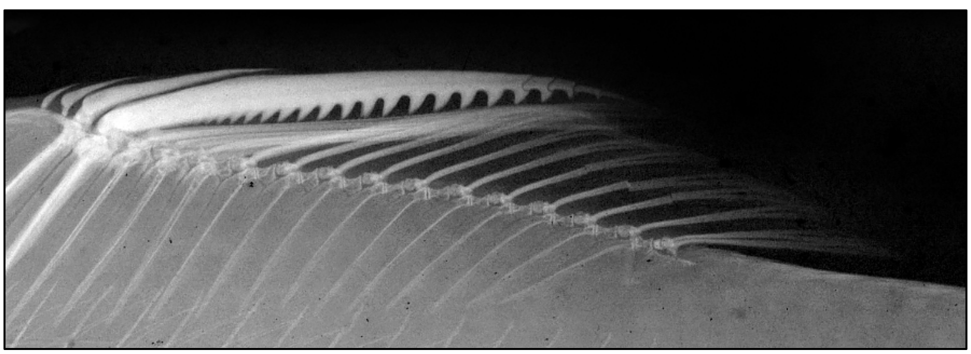
had been lost. The count then included that tooth.

4) Fin rays

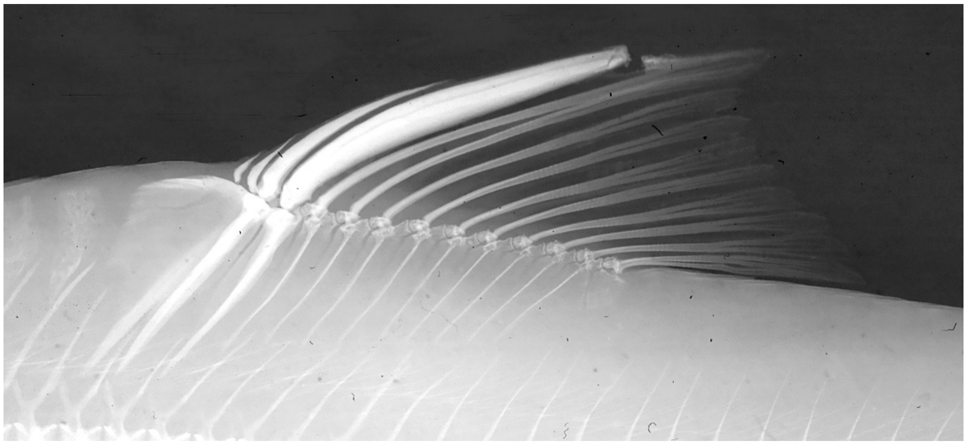
Counts of dorsal and anal fin branched rays can be diagnostic, other fins less so. The dorsal fin may have the last unbranched ray developed as a “spine” (not a true spine in cyprinoids) or hardened soft ray. This spine may be smooth or bear denticles (also called serrae) of varying size and extent along its rear margin. The extent of denticles can vary with age and size of individuals within a species so comparisons between species are only valid when fish of similar size are compared. Larger or older fish have weaker denticle development. There may also be individual and population variation.

a) Dorsal and anal fins

Fin ray counts were divided into two types. One count is of the unbranched, unpaired unsegmented rays and this is usually given in Roman numerals in the literature. In deference to some Iranian unfamiliarity with Roman numerals, the spine count is given in Arabic numerals in this text. Spine count included rudimentary rays which, at the anterior dorsal and anal fins, may be obscured by flesh or scales requiring some probing or dissection. Radiographs were often useful to confirm counts made under a microscope. The second count is of soft rays and is also indicated by Arabic numerals. These rays are usually branched, flexible, segmented and laterally paired. The last two unbranched rays usually arise from a single internal base and were then counted as one. This is generally the case in cyprinoids. Recent studies now include a half (½) to indicate this. This half count seems unnecessary, confusing as the ray is not half as long as its neighbour, and of course it is omitted in statistical analyses. The branched ray count is the most diagnostic and variable in such fishes.



X-ray of dorsal fin of *Cyprinion macrostomus*, NMW 52805,
showing four unbranched rays, the first small and probably not detectible without an x-ray,
the last a denticulated spine, followed by branched rays, the last two counted as one,
Naturhistorisches Museum, Wien.



X-ray of dorsal fin of *Systomus albus* (= *Carasobarbus luteus*), NMW 53680, showing ten branched rays, Naturhistorisches Museum, Wien.

b) Caudal fin

The branched caudal fin rays only were counted. Dorsal and ventral to these central rays are a series of unbranched rays which become progressively smaller and may be obscured by flesh and scales where the caudal fin attaches to the caudal peduncle. These are called procurrent rays. Counts in other works often comprise the branched rays plus one dorsal and one ventral unbranched ray. Caudal fin ray counts are remarkably uniform within families. In Cyprinoidei the count is almost always 17, except for occasional variants, and so is not cited. *Garra persica* was unique in having a strong modal count of 16 branched caudal fin rays.

c) Paired fins

Paired fin ray counts can be separated into unbranched and branched rays. A small splint or unbranched ray at the origin of the paired fins was excluded from the count. The posteriormost rays of these fins are not always branched but are included in the branched count. The branched ray counts were the most important and are the ones given here. However, in the pectoral fin the innermost rays were often difficult to discern and may develop or become apparent with age.

5) Scales

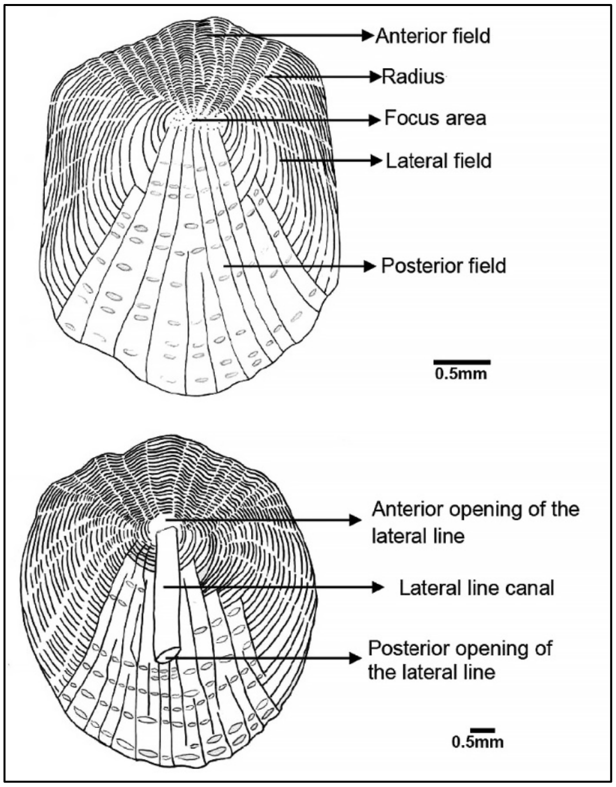
a) Lateral line count

The first scale counted was that scale contacting the pectoral girdle. The count continued along the flank following the pored scales and including small, additional scales lying between the large, regular scales as well as any unpored scales. The small, additional scales were relatively rare occurrences and any obviously abnormal fish - those with healed injuries for example - were not counted. The count terminated with the scale lying over the end of the hypural plate as determined by flexing the caudal fin. Some works recommend inclusion of a scale overlying the flexure only if most of its exposed field is closer to the body than to the caudal fin. Since the flexure of the caudal fin produces a relatively broad groove, this is difficult to judge in smaller fish. Therefore, the most posterior scale whose exposed surface touched the groove was the last scale counted. I have also continued the count onto the caudal fin in some species for a total count as this sometimes proved useful in comparison with counts in older literature.

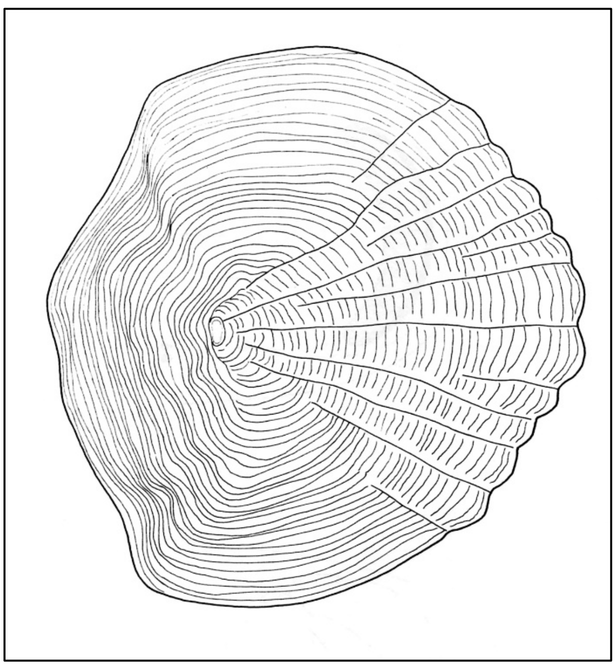
b) Scales above the lateral line

This count commenced with the scale at the origin of the first dorsal fin and continued down and back to, but not including, the lateral line scale. Any scale partially or wholly straddling the dorsal fin origin was counted as one scale. The count followed the natural scale row and included any small or irregular scales in the row.

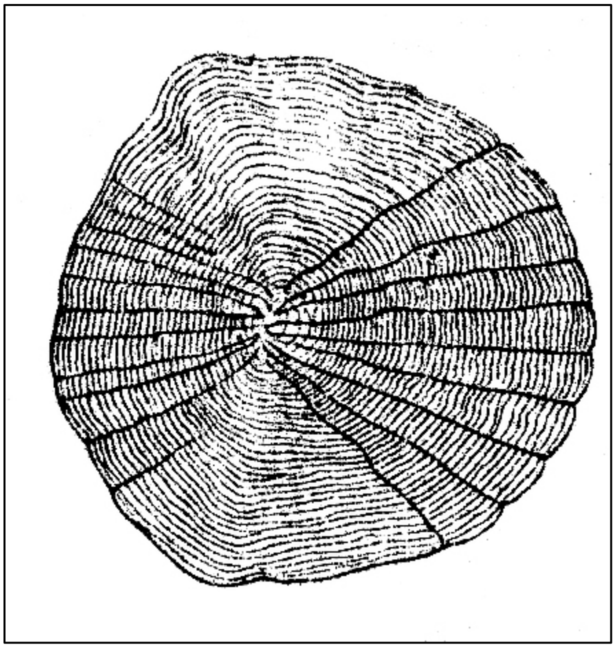
c) Scales below the lateral line
This count commenced with the scale at the origin of the anal fin, followed the natural scale row up and forward to, but not including, the lateral line scale and included any small or irregular scales. In this, and the previous count, it sometimes proved necessary to shift the counting row because of the scale arrangement. This was always a backward shift. In some instances there were several scales at the anal fin origin which overlapped each other very closely. All these were counted and account for the large degree of variation in counts between individuals of some species.
d) Scales between the lateral line and the pelvic fin origin
This count was made as in the above count.
e) Predorsal scale rows
All rows of scales between the origin of the dorsal fin and the head were counted just below the mid-line of the back on the upper flank. The final “row” at the occiput may consist of a single scale. This method was used because scales on the mid-line may be small and irregular, obscured by heavy pigment, or absent.
f) Caudal peduncle scales
This was the lowest count of the scale rows around the caudal peduncle, usually at its narrowest point (also called circumpeduncular scales). Both lateral line scales were included. Scale rows were counted even when the scale arrangement was such that occasional alternate rows touched. This count may be quite consistent between individuals of a species, but it may also vary markedly. The variation depended on the presence of large scales dorsally and ventrally on the caudal peduncle connecting the flank scale rows. When such large scales were present bridging over the top and bottom of the caudal peduncle, the total count could be, e.g., 12, but in some individuals two or more smaller scales occupied their positions so that the scale count jumped to 16.
g) Scale morphology
Scale morphology was based on scales removed from the flank below the dorsal fin (the embedded part of the scale is not readily visible *in situ*). The exposed part of the scale may be covered by heavily pigmented skin and need cleaning. Generally, morphology is generically different and sometimes between species. The main features of a scale are the overall shape (squarish to oval), the shape of the margins (the posterior margin almost always round and protruding, the dorsal and ventral margins straight to convex, and the anterior margin rounded, straight, wavy or with a central protuberance), the focus (the first part of the scale to appear in growth, usually central or subcentral anterior), the circuli (concentric rings around the focus, few to many depending on size and age of the fish/species), and radii (grooves radiating from the centre of the scale to the margin, some not extending all the way, varying in number, and present on the posterior area or field of the scale and variably present on the anterior and lateral fields).




*Capoeta saadii*, scale from between dorsal fin and lateral line above, and lateral line scale below, Azad Teimori.



Scale of *Chondrostoma regium* (anterior at left), showing a subcentral anterior focus, moderate numbers of circuli and few posterior radii, Friedhelm Krupp.



Scale of *Squalius latus* (anterior at left), showing a slightly subcentral anterior focus, moderate numbers of circuli and few anterior and posterior radii, after Keyserling (1961).

B) Morphometric characters

Morphometric data is on file in the Canadian Museum of Nature, Ottawa (CMN). Only selected information is included here as morphometric characters vary with sex, age and size, body condition (reproductive and seasonal; and environmental conditions including different habitat types such as marshes, streams, springs, large rivers and also desiccated habitats), and locality. Meristics are usually characteristic if taken from several localities and are not (mostly) variable by these limitations. Specimen size was also governed by available field gear in the 1970s (small seines) - many fishes housed in CMN are juveniles and sub-adults. Many of the newer described species are determined by DNA and "a combination of characters" so morphometrics may overlap for the reasons given above. Eighteen newly described species from Iran over the last 20 years averaged 29 specimens examined, only two species had sexes separated in morphometric analyses, only five species included fish from more than one locality (new cave fish species restricted to a single locality were not included in this summary), and the largest fish examined averaged twice the size of the smallest. Morphometric data is necessarily of limited utility under these conditions.

All measurements were to the nearest 0.1 mm using dial calipers. Measurements were taken on the left side unless a left fin, for example, was badly deformed or broken. Badly deformed specimens were not measured. Distortions due to preservation, such as a gaping mouth or expanded gill covers, were gently adjusted to as natural a position as possible.

The following list explains how the various measurements were taken. All measurements were taken in a straight line and not over the curve of the head or body.

1) Total length

From the anteriormost part of the head to the tip of either lobe of the caudal fin when that fin is normally splayed.

2) Standard length

From the anteriormost part of the snout (even when the lower jaw projects) to the end of the hypural plate (the end of the plate is found by flexing the caudal fin; in small fish it may be seen by shining a strong light through the caudal region). Standard length can be an inaccurate measurement. The end of the hypural plate is obscured by scales, flesh and caudal rays. Its position is determined by flexing the caudal fin; this flexure is taken to be the end of the hypural plate. Small fish have thin, delicate bones and the flexure may be at the anterior base of the hypural plate, at the origin of the caudal fin rays which articulate with and overlap the end of the hypural plate, or even between the last whole vertebra and the hypural plate. Large fish have a broad flexure which can give a variety of measurements by independent observers. Fortunately, in this study most fish were comparatively small and strong illumination helped to discern the end of the hypural plate. For larger fish I can only plead an attempt at consistency.

3) Head length

From the anteriormost part of the snout to the bony margin of the opercle (excluding the opercular membrane).

4) Body depth

Maximum straight-line depth excluding fins or fleshy and scaly structures at fin bases

5) Body width

Maximum distance from one side of the body to the other.

6) Head depth

From the occiput vertically to the breast or lower head surface.

7) Head width

The distance between the opercles when in their normal, closed position. The opercles are gently pressed into a closed position if greatly dilated.

8) Snout length

From the anteriormost part of the snout or upper lip at the mid-line to the bony front margin of the orbit.

9) Orbit diameter

Greatest diameter between the bony rims of the orbit. This distance is not always horizontal.

10) Postorbital length

Greatest distance between the posterior bony orbit margin and the bony opercular margin.

11) Interorbital width

Least bony width between the orbits over the top of the head in a straight line.

12) Predorsal length

From the base of the anteriormost dorsal fin ray to the tip of the snout or upper lip.

13) Prepelvic length

From the base of the anteriormost pelvic fin ray to the anteriormost point on the head (snout or upper lip).

14) Preanal length

From the base of the anteriormost anal fin ray to the anteriormost point on the head (snout or upper lip).

15) Length of caudal peduncle

The oblique distance from the insertion of the anal fin to the mid-point of the end of the hypural plate.

16) Depth of caudal peduncle

The least depth of this structure from the mid-line of the ventral surface.

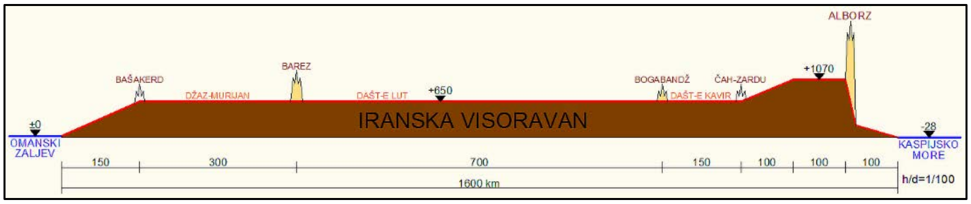
17) Length of the longest dorsal and anal fin rays

From the structural base of the ray to its tip.
18) Length of the dorsal and anal fin bases
From the anteriormost ray base (the origin of the fin) to the point where the fin membrane contacts the body behind the last ray (the insertion of the fin).
19) Length of the pectoral and pelvic fins
From the extreme base of the uppermost, outermost or anteriormost ray to the tip of the fin.
20) Distance between pectoral and pelvic fin bases
This and the following measurement are from the extreme base of the anteriormost, uppermost or outermost ray of the appropriate fin to the anterior base of the next fin.
21) Distance between the pelvic and anal fin bases
As above.
22) Length of fin spine
From the base of the spine to its tip. In more flexible spines, which may taper gradually as in many cyprinoids, this measurement includes the soft tip.

## Environment

### Geography

Iran is the second largest country in Southwest Asia (after Saudi Arabia with less than 20 freshwater fish species), has an area of 1,648,000 sq km and ranks fourteenth in the world in size, nearly as large as the British Isles, France, Italy and Spain combined (Firouz *et al*., 1970). It lies between latitudes 25°N and 40°N and longitudes 44°E and 63°E. Its northern border is shared with the former U.S.S.R. (Armenia (35 km long) and Azerbaijan (611 km) in the west opposite Iranian Azarbayjan, and Turkmenistan (992 km) in the east opposite Golestan, North Khorasan and Razavi Khorasan, and includes the southern part of the Caspian “Sea”, by far the world’s largest lake (436,284 sq km) and one of the deepest (1,025 m). The Iranian coastline extends for 740 km. The eastern border is shared with Afghanistan (936 km) and Pakistan (909 km). The southern border fronts on the Sea of Oman and the Persian Gulf, a coastline of 2,440 km. The western border is with Iraq (1,458 km) in the south and Turkey (499 km) in the north. Much of Iran lies at an average altitude of about 1,000 m, a feature found only in a few countries world-wide. Only Khuzestan, Sistan, the Caspian Sea coast and the Persian Gulf coast form lowlands. The coastal lowlands are quite narrow, often less than 20 km wide. Mountains are the most prominent feature of the Iranian landscape. The two major chains are the Alborz or Elburz, which rim the Caspian Sea basin in the north, and the Zagros which form a chain down the western side of the country. Inland of these chains lies the Iranian plateau, which is flanked on the east and south by lesser chains of mountains. The country has been likened to a bowl or saucer. This central plateau has extremely high summer temperatures and often very cold winters. The deserts of this plateau are barren and among the driest in the world. Rain falls only in winter. The terminal basins for streams and springs may be dry for years. There are extensive salt crusts, known as kavirs, over black, slimy mud and large areas are composed of hard, gravel plains known as dashts, prominently the Dasht-e Kavir and the Dasht-e Lut. Water is scarce in these regions, often restricted to small streams and springs. Larger rivers have their source in distant mountains. Between the Tigris and the Indus, only the Hirmand River on the Afghanistan border is large enough to be a river on a world scale - various “rivers” in the intervening area are really small streams easily fordable on foot for much of the year.

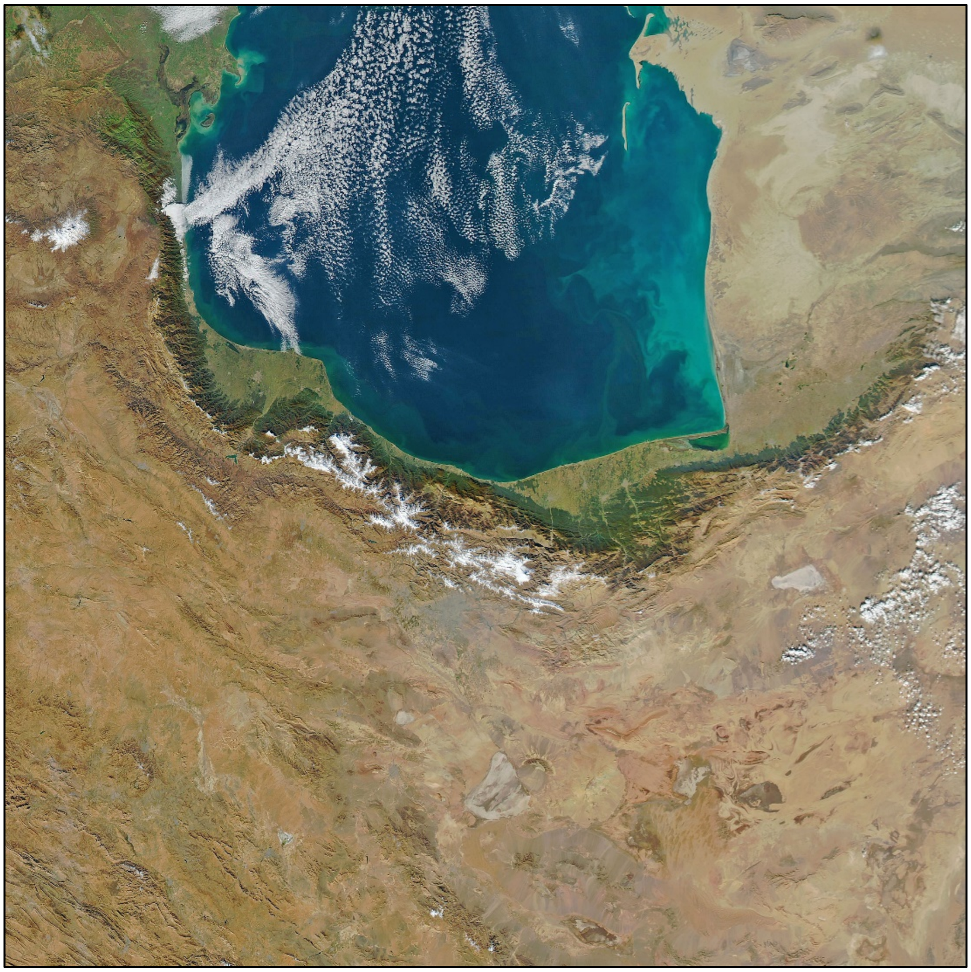



Section across Iran from the Sea of Oman to the Caspian Sea
(Iranrood Section, labels in Serbo-Croatian, CC BY-SA 3.0, Orijentolog).

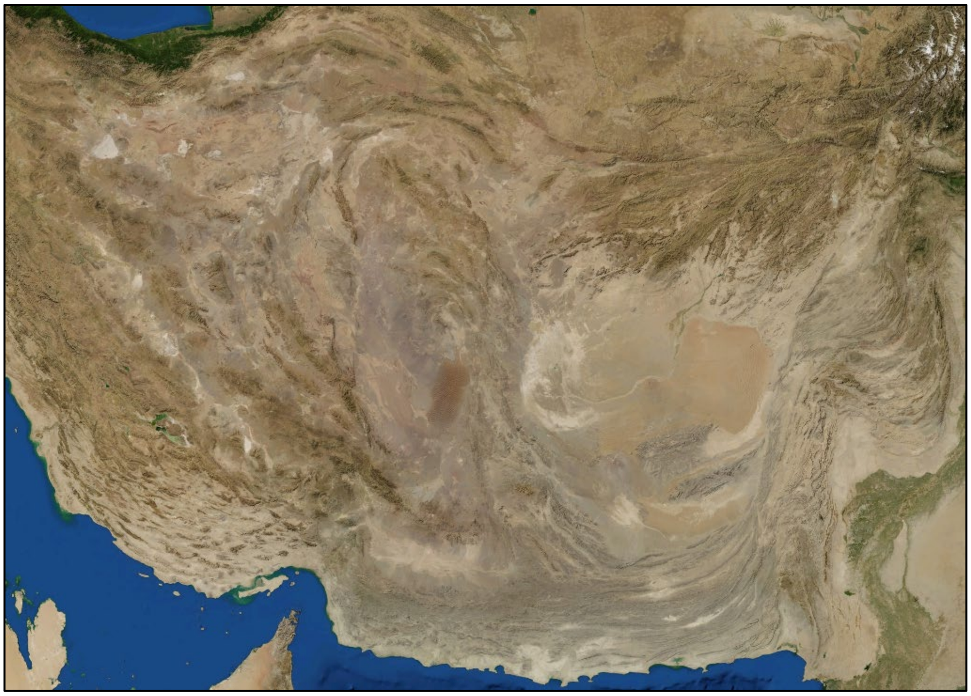
Iran and neighbouring countries, http://www2.demis.nl/worldmap/mapper.asp.

Persian Plateau
(CC BY-SA 3.0, Dbachmann).

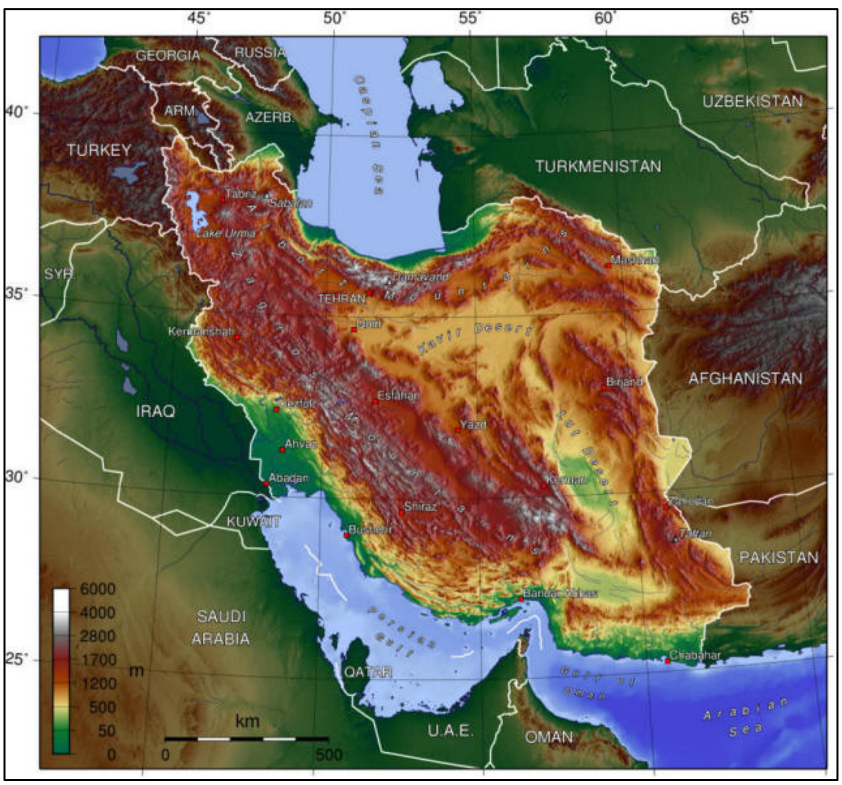
Exaggerated relief map of Iran
(CC0, NASA).



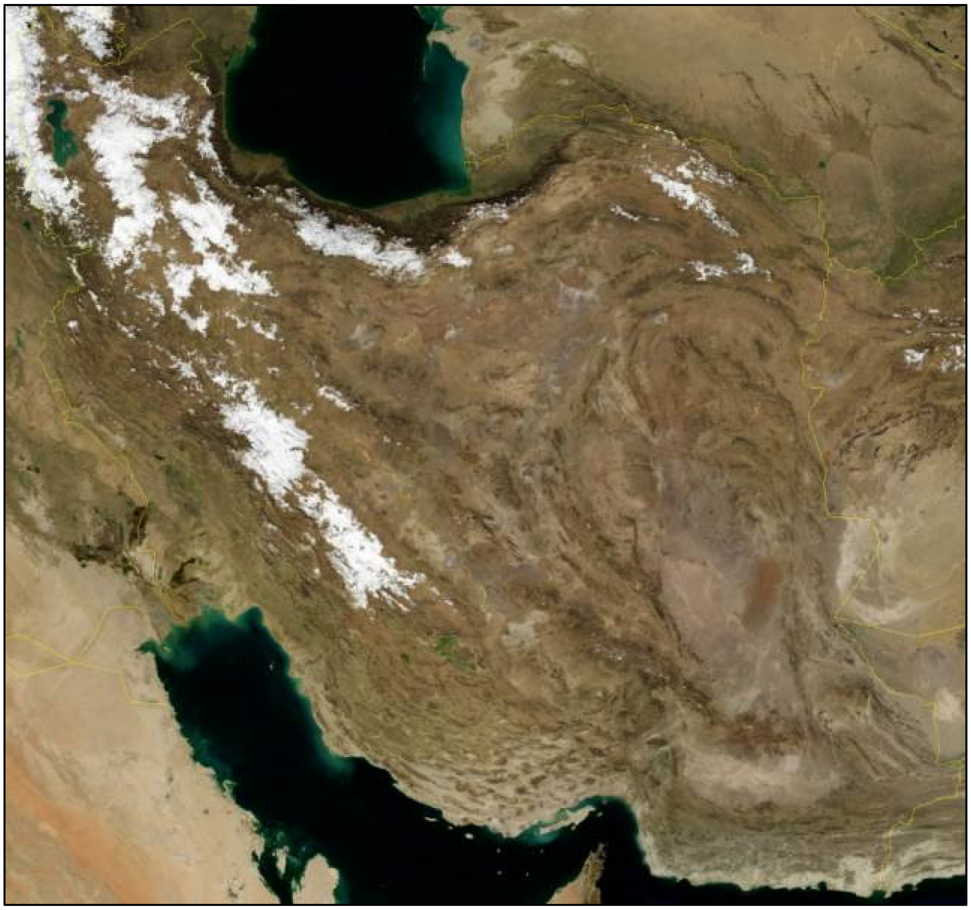
Southern Caspian Sea, green Caspian shore, snow-capped Alborz Mountains,
smog over Tehran (centre), and northern Iranian desert
(CC0, NASA).



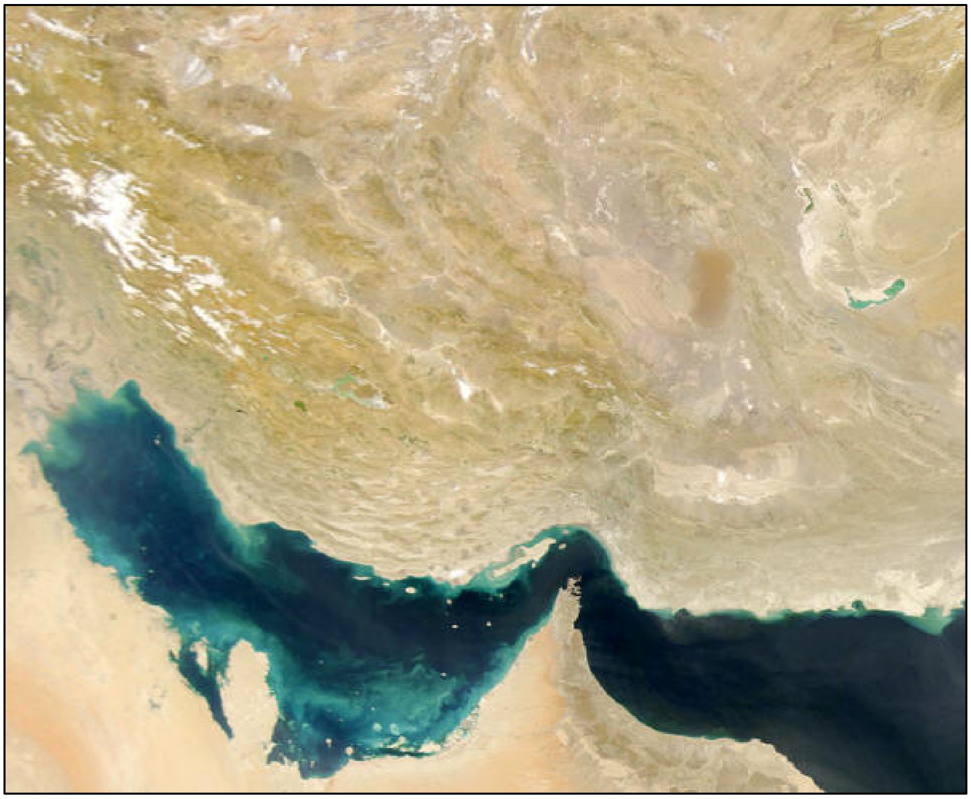
Central and eastern Iran with western Afghanistan showing dry kavirs and dry Sistan
(latter the pale area centre right)
(CC0, NASA).




Iran, topography and surrounding countries
(Iran topo, CC BY-SA 3.0, Captain Blood).



Iran, satellite view
(CC0, NASA).

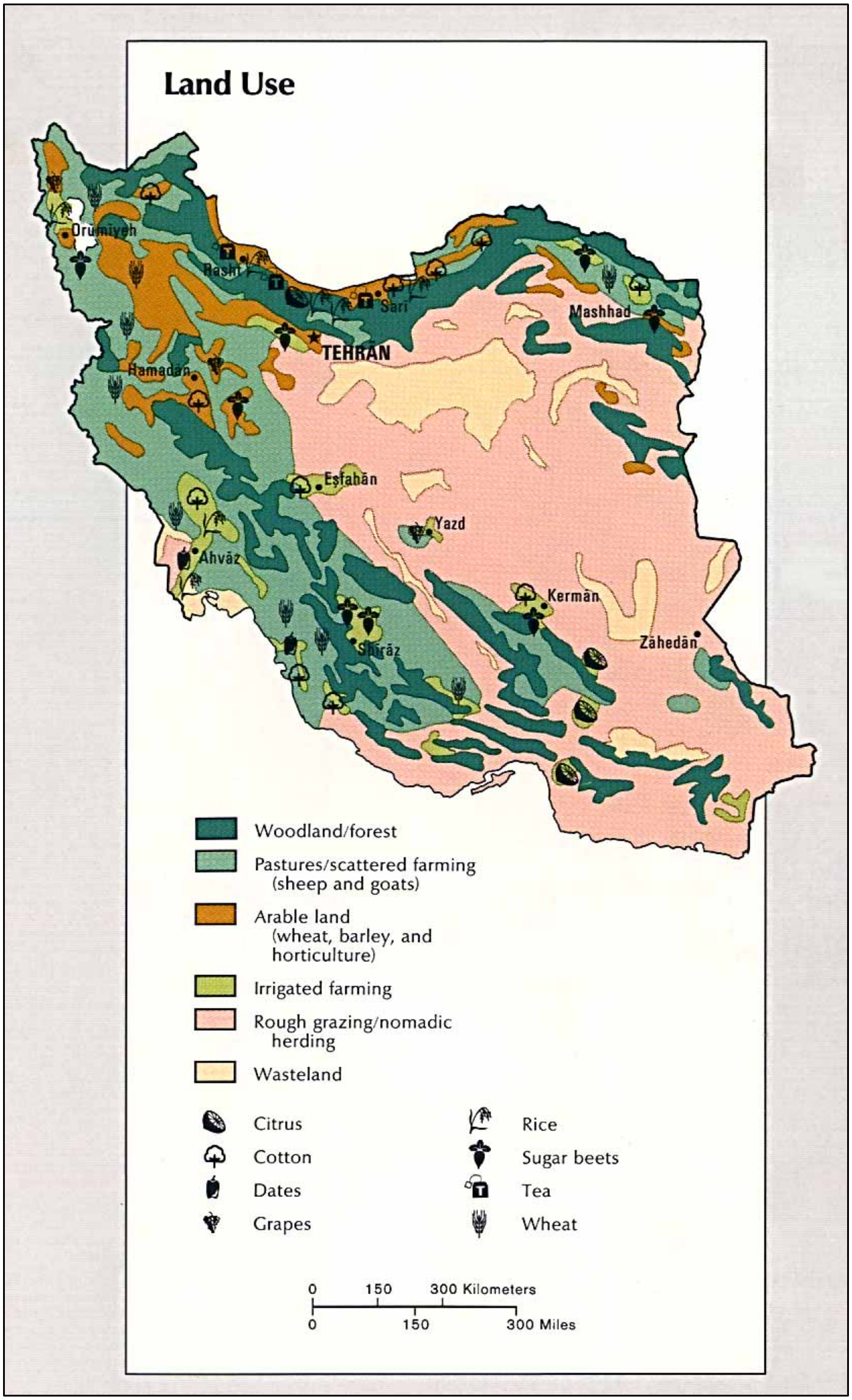


Southern Iran, Persian Gulf and Sea of Oman, Sistan at upper right
(CC0, NASA).

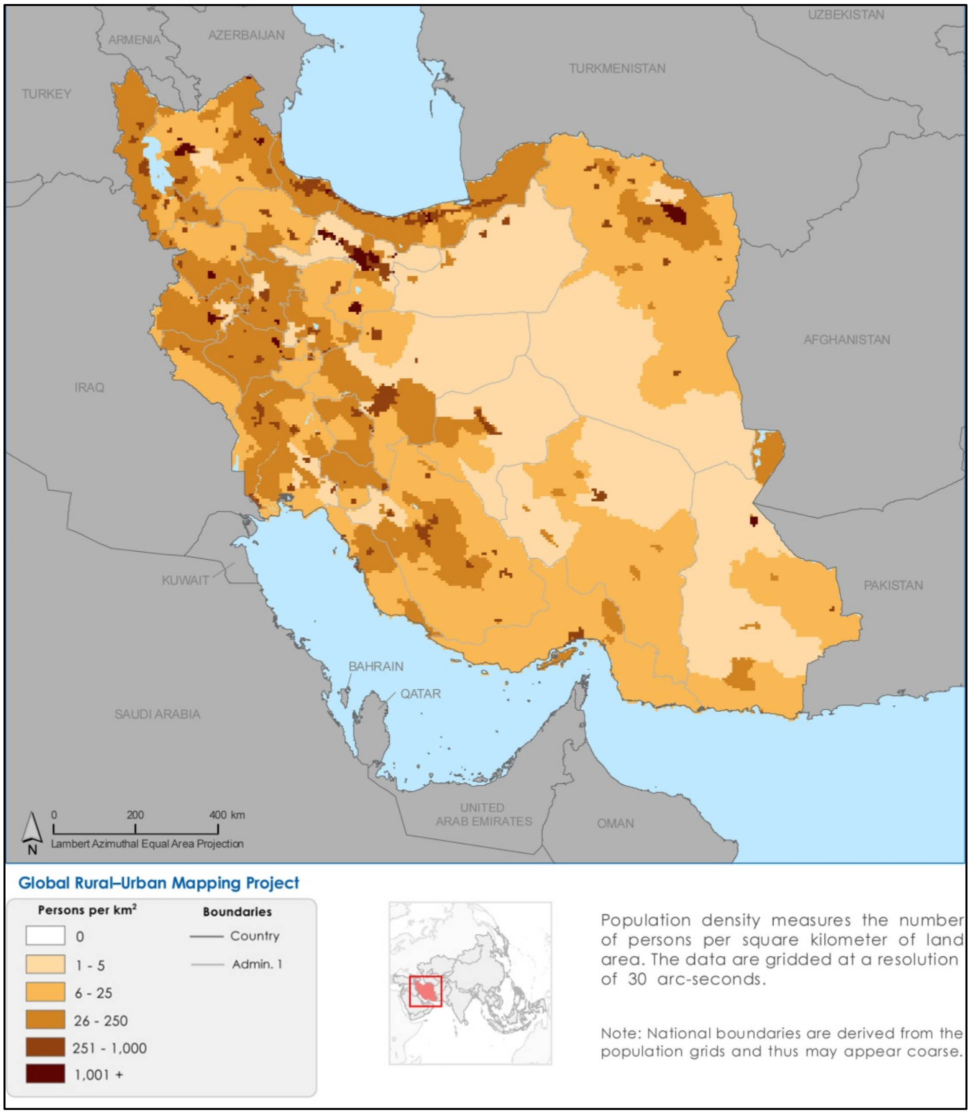
The total renewable water resource of Iran was estimated as 1°.5 cu km/year. 9 cu km/year are through transboundary rivers such as the Hirmand, Hari (= Tedzhen) and Aras and about 10 cu km/year is surface runoff to other countries notably Iraq. More than 1,900 km or 22% of Iran's borders are rivers (Chavoshian *et al*., 2005).

Fisher (1968) gave a general, physical geography and Breckle (1983) gave a general account of the features and life (excepting fishes) of deserts and semi-deserts in Iran. Barthold (1984) gave an historical geography of Iran and Yarshater (continuing) has many articles on geographical features. Geological literature was summarised in Dürkoop *et al*. (1979) and Davoudzadeh (1997). The website www.riversnetwork.org gives maps of some basins in Iran along with 3D flyovers.

Land use and population density in Iran are summarised by the following illustrations and these necessarily have effects on the fish fauna.




Land use in Iran
(Iran land, CC0, U. S. Central Intelligence Agency).




Iran population density, 2000
(Iran Population Density, 2000 …., CC BY 2.0, cropped, SEDACMaps).

It is pertinent here to interject a note on geographical names. Transliteration of Farsi place names into English is possible by more than one system and authors may just use their own interpretation. This results in variant spellings for geographical features in articles and on maps of Iran. For convenience, I have followed in the past the official standard names approved by the U.S. Board on Geographic Names. The Board published a gazetteer for Iran with a designation of the geographical place (e.g., lake, populated place, stream, spring, etc.) and its latitude and longitude. An online version is available at http://geonames.nga.mil/namesgaz/ but name interpretation continually evolves as noted below. I have often cited the literature source spelling followed by that of the U.S. Board on Geographic Names in parentheses where these differ markedly. Some variations are obvious, e.g., Totkabon, Tootkabon, Totkebon or Tutkabon, and only the Board name may be used.

I have not included the diacritical marks used in the Board's system. They would be of little help to those unfamiliar with Farsi and perhaps unnecessary to those who are. Needless to say, there are variant diacritical marking systems and, in any case, pronunciation varies

throughout Iran, which has several languages and dialects in addition to the predominant Farsi or Persian.

The situation is further complicated by transliterations into other European languages and readers should be aware of this when reading non-English papers on Iran or Iranian fishes, e.g., the English Shiraz is Chiraz in French, and Genu, a southern hotspring locality, has such variants as Ginau, Genow, Gueno, Geno, and finally Ginao from the German transliteration, hence the trivial and eponymous name of the aphaniid *Aphaniops ginaonis*. As if this were not enough, the vagaries of political fortune are writ large upon the face of Iran (which used to be Persia). Bandar-e Pahlavi has reverted to its older name of Anzali (often spelt Enzeli on older maps), Reza'iyeh to Orumiyeh (= Urmia in older English literature and now in more recent papers), and so on.

Another complication is the tendency for long rivers to have several names along their course, sometimes taken from the nearest population centre, and for locally used names to be different from map or gazetteer names. Names also vary with language and through time. One of the major rivers of Fars Province appears on maps as the Mand River or more correctly Mond River, but near Shiraz its reach is called by its Turkic name Qarah Aqaj (also transliterated Qara Aghach, Qareh Aghaj, Qara Agach, Qareh Aqaj, Qareh Aqach, Kara Agach, Kara Agatsch and Kara Agaj). The Kor River, also in Fars, is known in older papers as the Araxes River which is not the same as that forming the border between Iran and the former U.S.S.R. (which anyway is often spelt Aras or Araks).

Certain Farsi words appear in place names and can lead to tautologies. The Sefidrud or Safidrud (literally White River) may appear as Sefidrud River in literature but is here given as Sefid River for clarity (it very seldom appears as the direct English translation White River). Wherever a river has "rud", "rudkhaneh" or "rud-e" as a component it is mostly replaced here by river. Some rivers always appear as …rud, perhaps in reference to the district where they are found, and this may be retained here, e.g., Shirud never seems to appear as Shir River and the Shah River usually appears as Shahrud. In northwest Iran, many streams and rivers incorporate the word "chay" (or "chai") and the former may be retained here or omitted where a series of river names are given. Some individual streams and rivers here may be variously referred to as "chay" or "river" in literature sources but a consistent usage is attempted here.

Other, mostly Farsi words in place names having a geographical meaning, appearing on maps and in the literature, often without explanation, along with some ichthyological terms, and variant spellings are:-

ab = water, intermittent stream, stream, spring;
ab-bandan = natural, shallow, freshwater wetlands or ponds on the Caspian plain often used for duck hunting in winter and water storage for irrigation in the dry summer; contains fish;
abad = a suffix indicating an inhabited place;
ab ambar = cistern;
ab anbar = cistern, artificial and roofed, usually fishless;
ab-e garm = hot spring;
ab-e shur = salt river, common name of salty rivers;
abshur rud = salt river, common name of salty rivers;
anbar = tank, if an open surface structure may contain fish;
ateshkade = fire-temple (archaeological feature);
av = stream;

`ayn = spring;
bagh = garden;
bahr = sea;
Bahr-e Khazar = Caspian Sea;
baksh= municipality;
band = dam, reservoir, lake (old dams for water storage - sadd in Farsi for modern dams);
bandar = port, harbour, anchorage, bay;
bankari = constructing temporary weirs for water diversion;
bar andaz = halting place;
barm = marsh, lake, pond;
batlaq = marsh, swamp;
biaban = desert (also the name of the coastal plain south of the Minab River to the cape of Ra's al-Kuh in Hormozgan Province);
berkeh = tank, pool, cistern;
birkat = pool, well, marsh, lake;
borj = fort, tower;
botlaq = marsh, swamp;
caviar = sturgeon eggs as food; some cyprinoid eggs may be termed caviar and eaten;
çay = stream or river;
chah = well, spring, cistern;
chai = stream or river;
cham = stream, gorge;
chashmeh = spring, well;
chay = stream or river;
cheng = hill, mountain, promontory;
cheshmeh = spring;
centner = 100 kg (used in Russian texts as a measure of commercial catches; sometimes given as 50 kg elsewhere but internal evidence in Russian papers indicates 100 kg is correct);
dag = mountain;
dagh = mountain;
dahaneh = section of a stream, gorge, pass, defile, water gap;
damagheh = cape, promontory;
damgah = an artificial, freshwater wetland, maintained primarily as a duck-hunting area but also used for irrigation during the dry summer months;
daqq = salt flat, salt depression, salt waste, marsh, intermittent salt lake;
darband = gorge or pass;
darreh = stream, valley, gorge, ravine;
darya = sea, stream, intermittent stream, channel;
Darya-ye Gilan = Caspian Sea;
Darya-ye Khazar = Caspian Sea;
Darya-ye Mazandaran = Caspian Sea;
daryacheh = lake, marshy lake, stream;
dasht = plain, desert, steppe, depression, upland, open country, field; usually dry desert with a firm base of pebbles or silts;
deh = village;
dehkadeh = village;

Dejleh = Tigris River;
dez = fortress;
echbel = eggs of fishes other than sturgeons as food;
emamzadeh = tomb, shrine;
eskeleh = jetty;
estakhr = pool;
farsakh = the distance a horse or camel could walk in an hour, given as a measure of distance in the 1970s in Iran but very flexible (rough ground, uphill, sand, tired animal, etc., or just a generalisation). About 6-7 km (sources vary) or as the metric farsakh fixed at 10 km, and needless to say there are several local variations;
gadik, gaduk = pass;
galal = stream;
gardan, gardaneh = pass;
garmsir = hot country, winter quarters in the lowlands;
ghadamgah = a religious site; usually no fishing allowed;
gharb(i) = west(ern), as in the province Azarbayjan-e Gharbi;
godar = pass;
göl = lake, marsh, swamp (Turkish);
gölü = lake, marsh, swamp (Turkish);
gowd = depression;
hammam = bath;
hamun = marshy lake, salt waste;
hawr = marsh, lake;
hesar = fort, castle;
hor = marsh;
howr = marsh;
howz = tank, cistern, pond, pool, lake, reservoir, spring;
il’men = a shallow, flood-plain lake heavily overgrown with reeds and rushes (Russian);
ishan = hill;
istgah = railway station;
jabal = hill, mountain;
jangal = forest (hence jungle in English);
jar = stream;
jazirat = island;
jazireh = island;
jebal = hill, mountain;
jehil = lake;
jolgeh = plain;
jonub(i) = south(ern);
ju = stream, irrigation channel;
jub, jube = irrigation channel, watercourse, gutter, ditch; city jubes have water for only part of the day and are fishless but jubes fed from a qanat may support a fish fauna;
juy = stream, watercourse;
kal = stream, intermittent stream;
kalleh = peak;
kamar = hill, mountain, ridge;

kani = well;
karavansara = caravansary;
karez = underground irrigation channel (a qanat);
kaur = stream;
kavir = salt waste, salt desert, marsh; usually a salt crust over silt deposits which can be fatal mires of slimy mud (= playa);
khalij = bay, gulf;
Khalij-e Fars = Persian Gulf;
kharabeh = ruins;
khirr = stream;
khowr = inlet, channel, bay, bight, tidal creek, estuary;
khwar = stream;
kotal = mountain pass;
kowr = stream;
kuh = mountain, range, hill, peak, ridge, spur;
kuhha = mountains, range, hills;
liman = a brackish bay of the sea, usually at a river mouth, sometimes cut off from the sea but still brackish; also an estuary (Russian, mordab or talab in Farsi);
lut = desert;
mahur = hill;
mandah = stream;
markazi = central, as in Markazi Province;
masjed = mosque;
mordab = lagoon, backwater, creek, swamp, stagnant water (literally dead water, used in earlier literature, now replaced by talab);
nahr = river, stream, canal, docking basin;
naizar = reed swamp (Sistan);
namak = salt; usually a salt lake with open water or a salt crust but without much mud;
namaksar = salt waste;
naveh = stream;
nawah = stream;
nehri = stream;
neizar = reed swamp (Sistan);
ostan = province, governorate-general;
ozero = lake (Russian);
pal = hill, mountain;
paskuh = mountain range;
pereval = pass;
poshteh = hill, mountain;
qabr = tomb;
qabrestan = cemetery;
qal’at = fort;
qal’eh = fortress;
qanat = underground irrigation channel; an adit shaft (see Coad (1996f) for details);
qasr = fort;
qolleh = hill, mountain, peak;

ramlat = sandy area;
ra’s = cape, point, promontory;
reka = river;
reshteh = mountain, mountain range, hill, spur;
reshteh kuh = mountain range;
rig = sand area, dunes;
riz ab = stream
roga = outflow (in the Enzeli or Anzali Mordab or Talab);
rud = river, stream, intermittent stream;
rudbar = valley drained by a river with flowing water; place watered by many streams;
rudkhaneh = river, river bed, watercourse, intermittent stream;
rusta = village, inhabited place;
sabkhat = salt marsh, lake;
sadd = dam, reservoir (used for modern dams); dam is used here rather than the Farsi word;
saddi qanat = a qanat drawing water from a dam;
sahel = coast, beach, shore;
sar = cape;
sarab = spring (in western Iran), literally “beginning water”;
saray = caravansaray;
sardsir = cold country, summer quarters in the highlands;
sarhadd = frontier;
saydgah = fishing station, as along the Caspian coast;
sazhen = a marine sazhen equals 1.83 m (Russian);
selseleh = mountain range, mountains;
shahr = town, city;
shahrdari = municipality;
shahrestan = district;
shahzadeh = shrine;
shamal(i) = north(ern);
sharq(i) = east(ern), as in the province Azarbayjan-e Sharqi;
shatt = large river, bank of a river, stream;
shebh-e jazireh = peninsula;
shekasteh = hill, mountain;
shil = a wooden barrier erected across a river for catching fish; hence shilat (in Gilaki, the Persian dialect of Gilan);
shilat = fisheries company;
Sherkat Shilat = Northern Fisheries Company concerned with the Caspian Sea;
Shilat Jonub = Southern Fisheries Company concerned with the Persian Gulf;
shur = salt (a common river name), brackish, salt stream;
shurab = salt water;
shurehzar = salt stream, salt marsh;
su = water, stream, river;
suyu = stream;
talab = more modern version of mordab, *q.v.*;
tall = hill, mountain, spur;
tang = pass;

tangeh = valley;
tappeh = hill, mountain, mound;
tell = hill;
tepe = hill, mound (often an archaeological site);
vareh = a small dam;
vilayet = province (Turkish);
ziarat = shrine.

The early geological history of Iran and neighbouring areas has necessarily affected the distribution of fishes, facilitating dispersal or hindering it, isolating or joining species. Some historical features are discussed under the appropriate drainage basin descriptions below or under the relevant genus or species but others are more widespread and are briefly outlined here. Sources include, in particular Wolfart (1987), but also Harrison (1968), Takin (1972), Falcon (1974), Stöcklin (1968, 1974a, 1974b), Krinsley (1970), Stoneley (1974), Kashfi (1976), Shearman (1976), Booth (1977), Jackson and Wood (1980), Berberian and King (1981a, 1981b), Haynes (1981), Rögl and Steininger (1984), Šengör (1984), Oosterbroek and Arntzen (1992), Rögl (1998, 1999), Adams *et al*. (1999), Esmaeili *et al*. (2014) and Hou and Li (2018). Popov *et al*. (2004) gave explanatory maps showing changes over time from the Late Eocene to the Pliocene. Zoogeographical analyses were based on present day distribution and suppositions on relationships. During the Cretaceous and through the Early Oligocene the Tethys Sea, several thousand kilometres wide, extended from the Mediterranean Sea to the Indian Ocean, separating the Afro-Arabian and Eurasian continents. Afro-Arabia was part of Gondwanaland. The usual assumption is that Iran belongs to Eurasia, perhaps with Central Iran a microcontinent or island or as a northern continuation of Arabia, and with East Iran a microcontinent or peninsula of Eurasia. Förster (1976), however, maintained that Central Iran, and probably North Iran, were part of Gondwana. The Tethys covered much of what is now Iran and was a barrier to the movement of freshwater fishes. The ocean regressed during the Late Oligocene except for a Euphrates-Persian Gulf furrow and the Zagros and Makran troughs. Continental sediments were deposited in endorheic basins of Iran. The Tethys closed in the Middle to Late Miocene as evidenced by mammal migrations between Asia and Africa. The establishment of continental conditions over Iran has been continuous since the Late Miocene, except for an inundation in the Late Pliocene in the Zagros trough and the Makran coastal region. There may also have been an early Miocene connection between Arabia and Iran/Iraq allowing movements of freshwater fishes (Adams *et al*., 1999). Iran is therefore composed of parts of Gondwana, which was the continent south of the Tethys, welded to the northern continent and parts of the Eurasian plate (such as the central and eastern Iranian microcontinent). The northeastward movement of the Arabian Plate caused the closure of the Tethys and led to the folding, which in the Miocene/Pliocene orogenies, formed the Zagros Mountains, a prominent feature of western Iran important in zoogeographic studies of fishes (see Kashfi (1976) for an opposing view).


Zagros Fold and Thrust Belt
(ZagrosFTB, CC BY-SA 3.0, Mikenorton).

The Zagros orogeny is related to the opening of the Red Sea, which formed a barrier to fish dispersal. The Alborz Mountains are a northern part of the Alpine-Himalayan orogen of which the Zagros are a southern part and started to rise in the upper-lower Pliocene (Krinsley, 1970; Stöcklin, 1974). A continuous land bridge between Eurasia and Africa has been in existence since the upper Miocene, facilitating freshwater fish dispersal. Hora (1937) and Menon (1957) referred to wet, marshy, tropical conditions and headwater captures along the whole southern face of the Himalayas and westwards during the Pliocene and early Pleistocene facilitating the spread of fishes from the east to Iran. Hora (1937) and Briggs (1987) considered that cyprinoids entered Africa from Southeast Asia 18-16 MYA, in the early Miocene, while other groups moved through Iran and the Arabian Peninsula beginning in the early Eocene. Kosswig (1951, 1952, 1955a, 1955b) noted the similarity at the generic level between Indian and African fishes, e.g., the cyprinoids *Barilius*, *Garra* and *Labeo*, indicating that these fishes arrived in Africa from India after the desiccation of the Syrian-Iranian Sea in the Pliocene. The primary route, according to Kosswig and to Por (1987), was a northern one around the barrier of the Persian Gulf and Sea of Oman via northern Arabia, Syria and the Levant. Cooling conditions in these areas during the Pliocene and especially the Pleistocene glaciations, and arid climates at times, were unsuitable for tropical forms. These movements left a selection of fishes in what is now Iran including the cyprinid *Garra*, the sisorid catfish *Glyptothorax* and the spiny eel *Mastacembelus*.

The Pleistocene foredeep of the Himalayas may have had connections with the Tigris-Euphrates basin which extending down the Persian Gulf as a river valley. The Tigris-Euphrates basin formed during the Pliocene and was colonised by primary freshwater fishes no earlier than the late Pliocene (Krupp, 1983). Movements of fishes into Iran from the west and north were also affected by the presence of the Tethys Sea and a brief account is given under the genus *Barbus*

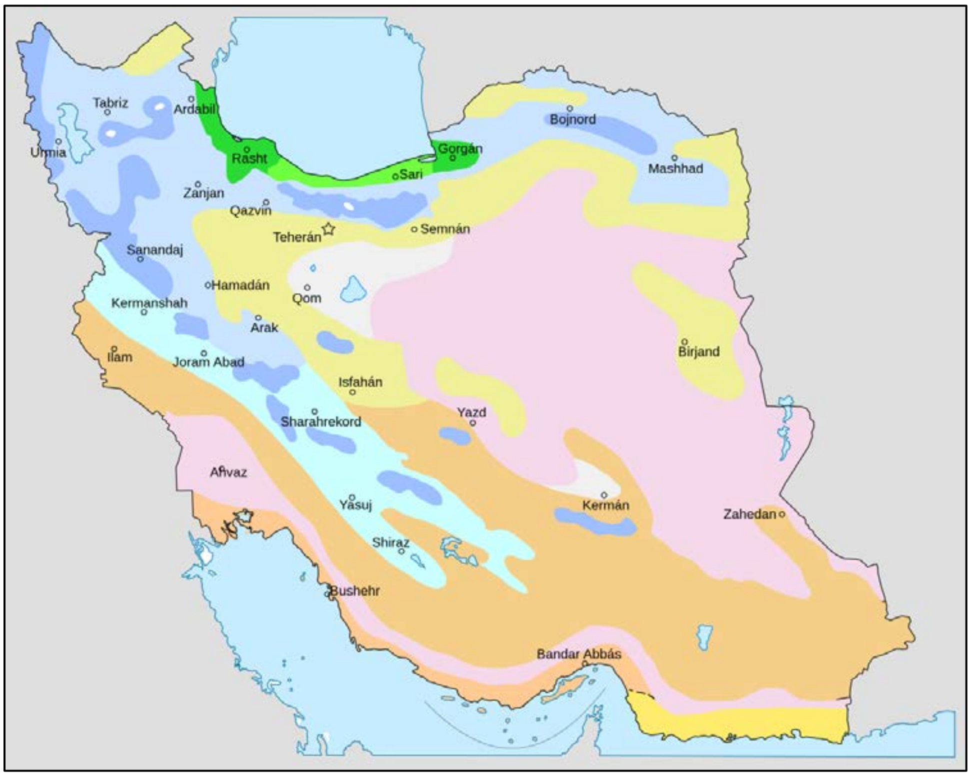
*sensu lato* that has been studied in this regard.

The present picture of the Arabian Peninsula is of an arid desert unsupportive of fish life. The presence of fishes in Arabia and the Levant, and even Africa, with apparent relationships to fishes from Iran and the east indicate that fishes must once have traversed this area. Movements of fishes are thought to have been in a northern arc around the Fertile Crescent or its earlier version. However, this modern picture is perhaps illusory as there is evidence of a more hospitable environment in the Arabian Peninsula at various times in the past. Wadis were active during "pluvial" periods of the Pleistocene as evidenced by deposition of fluvial material (Al-Asfour, 1978). One of these wadis drained much of central Arabia to the Kuwait area. The "Kuwait River" once ran from the Hijaz Mountains in western Saudi Arabia northeastwards for about 850 km to drain into the Persian Gulf via a vast delta occupying much of modern Kuwait. The river was 8 km wide and over 15 m deep along most of its length (Hamblin, 1987; Anonymous, 1993a). This river last ran between 11,000 and 6,000 years ago and could have provided a highway for fish dispersal. Earlier rivers of this nature dating to the Late Miocene (Forey and Young, 1999; Hill and Whybrow, 1999; Friend, 1999), to the Pliocene (Gerson, 1982), and others like it in other parts of the peninsula, as well as shallow lakes (e.g., Lake Mundafan in the Rub' al Khali at 36,000-17,000 B.P. and again at 9,000-6,000 B.P.) would have facilitated transfer of species across the Arabian Peninsula, today an impassable desert for fishes, e.g., at the height of the Würm glaciation 40,000 years ago (Chapman, 1971; McClure, 1976; Al-Sayari and Zötl, 1978; Brice, 1978; Jado and Zötl, 1984; Wagstaff, 1985). A freshwater connection between Iran and Arabia was almost continuous from 70,000 to 20,000 years B.P. (Krupp, 1983). However, no fish remains have been found in the late Pleistocene lakes although freshwater molluscs are frequent, *Hippopotamus* remains are reported and Neolithic fishhooks have been found in Al Hasa in eastern Saudi Arabia. Incomplete Miocene freshwater fish fossils are reported from the Jizan basin in the Tihama north of the Saudi Arabian-Yemen border (Brown, 1970). One was identified as a *Barbus* and the other as a *Tilapia* (Cichlidae). Both these identifications are of such a general nature (see account on the genus *Barbus* and related genera for example) as to throw little light on history or relationships with modern taxa. The Lower Miocene fauna of Al-Sarrar at 15-17 MYA, northwest of Dhahran in eastern Saudi Arabia, contains pharyngeal teeth thought to be *Barbus sensu lato* and, more interestingly, several thought to be *Labeo* (Thomas *et al*., 1982). This latter genus is not now found in the Middle East but occurs in the Indian subcontinent and Africa. The Late Miocene Baynunah Fauna of Abu Dhabi in the United Arab Emirates contains *Clarias* (airbreathing catfish), *Bagrus shuwaiensis* (bagrid catfish) and *Barbus sensu lato* in a river connected with an ancestral Tigris-Euphrates system (Forey and Young, 1999). These fossils tend to confirm the hypothesis that fishes of Asian origin reached Africa through the Middle East and could have taken what may be termed a southern route across the Arabian Peninsula. However, Forey and Young (1999) pointed out that the modern Arabian fauna may not have a history stretching back to the Miocene but is due more to a re-invasion after a loss of an earlier fauna. The modern Iranian fauna, in part, may be a remnant of movements at various times yet to be resolved in the absence of species-level phylogenies.

Zoogeographical information is given in the description of drainage basins below, in the introduction to the Carps and in the Species Accounts.

## Climate

The general climate of Iran is based on Bobek (1952), Ganji (1960, 1968), Taha *et al*. (1981), *Aquastat* from the Food and Agriculture Organization, Rome (www.fao.org/ag/agl/aglw/aquastat/iran.htm) and www.bibliothecapersica.com/articlenavigation/index.html, under ab (= water) and climate, downloaded 24 December 2004. Climate (along with landforms and terrestrial ecosystems) are also summarised in Azizi Jalilian *et al*. (2020). Kouchoukos *et al*. (1998) gave an overview of climatology for Southwest Asia based on satellite datasets. Precipitation, its amount, nature and seasonality, is important in determining the water regime and thus the habitats for fishes. Iran is sparsely vegetated, both naturally and through the agency of man, and the air temperature and amount of insolation has a direct effect on water temperatures. Insolation is continuous through summer days when clouds are a rarity over much of Iran and the weather remains settled for weeks at a time.




| | | | | | |
|---|---|---|---|---|---|
| Caspian Mild and Wet | Caspian Mild | Mediterranean with Spring Rains | Mediterranean | Cold Mountains | Very Cold Mountains |
| Cold Semi-Desert | Hot Semi-Desert | Dry Desert | Hot Dry Desert | Hot Coastal Dry | Coastal Dry |

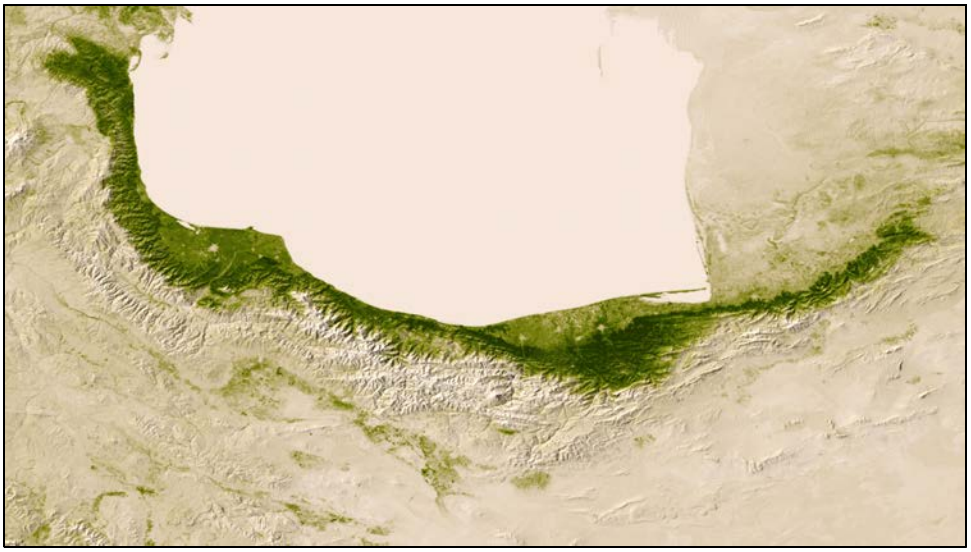
Iran Climate Map,
(Iran-climate-map-es, CC BY-SA 4.0, Siamax).

In general, the climate of Iran can be classified as arid to semi-arid, with more than 80% of the country characterised by less than 250 mm annual rainfall. Mountain ranges block off the interior of Iran and give extremely continental conditions except for the narrow littoral zones on the Caspian shore and the Persian Gulf. Summers are hot and dry with little change from day to day. Three main climatic types are found:- warm, temperate and rainy with a dry summer in the Caspian coastal area, dry, hot desert in the central plateau, and dry, hot steppe in the rest of the

country. Humidity is generally low because of the altitude, much of Iran being over 1,000 m average height. Coastal regions along the Persian Gulf have a high humidity, especially in summer. Wind patterns are deflected by the Zagros and Alborz ranges in the west and north. Summer winds are mainly north and northwest over much of northern and central Iran and are hot, dry, and strong for long periods. The Sistan "Wind of 120 Days" from the northwest blows from the end of May to September continuously and is very hot, dry and sand-laden. The "shamal" blows from the northwest over Khuzestan and coastal regions of the Persian Gulf from February to October, most intensely in summer. These summer winds undoubtedly contribute to the desiccation and, in some cases, filling-in of watercourses. In the south, the winds are west and southwest.

Temperature varies greatly over Iran with latitude and altitude, as well as with the seasons. Winter lows are found in January and summer highs in July in general, with the Zagros and Alborz mountains and the Caspian shore having maximum temperatures in August because of the influence of altitude and the sea. The mean monthly temperatures for January at 15 selected stations across Iran (Ganji, 1968) had a range of -1°C to 20°C, average about 8°C. For July, these figures are 25 to 37°C, average 30°C. The annual range is 14C° at Jask on the Sea of Oman and 30.5C° at Mianeh in East Azarbayjan. Outside the coastal areas of the Caspian Sea and Persian Gulf, the annual range is considerable, and daily ranges are large. Nights can be very cold in the northeast, less so on the plateau. Some areas, like the Khuzestan plains, have maximum temperatures over 50°C (53°C at Gatvand near Dezful; possibly over 55°C in the interior, hotter than anywhere else on earth) in summer while in the northwest in winter the temperature can fall below -30°C (to a low of -36°C at Bijar in Kordestan). Five temperature provinces have been delineated for Iran:- the Caspian zone along the littoral which has a low annual temperature range; the Persian Gulf zone which has a low annual range but high values; the Zagros zone with a much higher range than the first two zones and a very low January mean; the Alborz zone which is similar to the Zagros but has higher temperatures and a greater range; and the interior zone with the greatest annual range coupled with relatively high values.

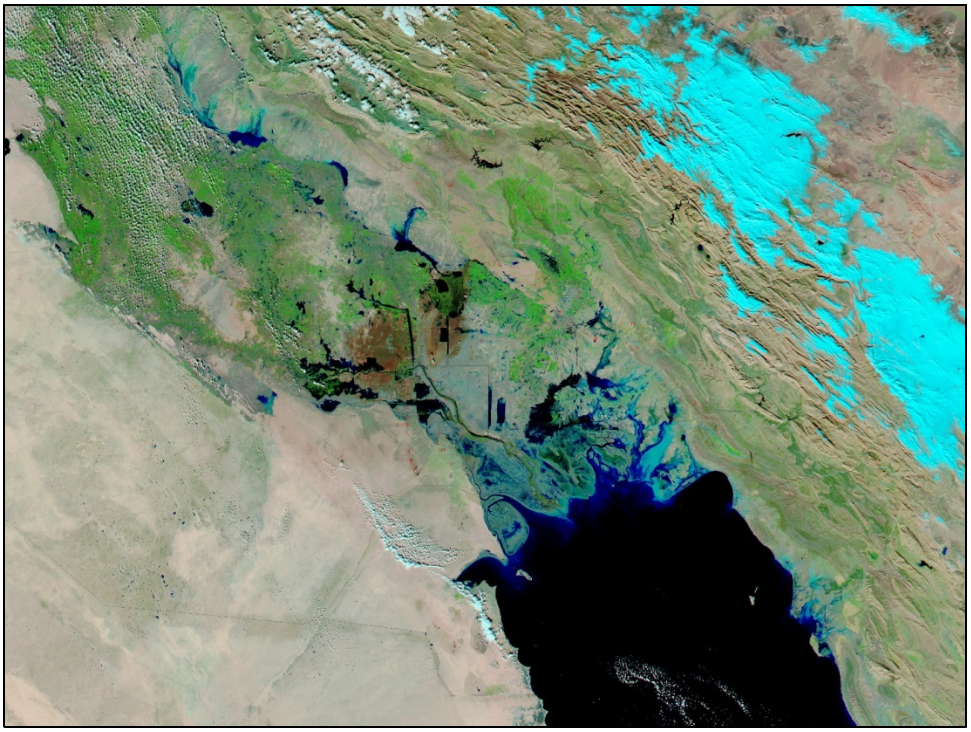
Modarres (2006) reviewed precipitation climates in Iran which vary regionally and from year to year. Precipitation falls in winter as snow on the mountains of the north and west. The highest mountains remain snow-covered year-round. The plateau also receives snow but it does not last long and there is no snow along the Persian Gulf coast. Rain falls mainly in November to May with a mean annual of 416 mm, although the Caspian littoral is much higher and the interior plateau much less. Rain is uncommon from May to October over most of Iran. Maximum rain is found on the outward slopes of the Alborz and Zagros ranges where the mean annual rainfall is more than 1,200 mm, 1,950 mm at Anzali. The plateau has less than 120 mm annually, Sistan less than 70 mm, and Mirjaveh on the Pakistani border only 48 mm annually. The Caspian littoral has rain in every month at some localities. The plateau receives most of its rain in spring, the Caspian in autumn, and the Gulf coast in winter. The result of this pattern of rainfall is heavy runoff in spring with silt-laden floods and erosion a feature. Many streams marked on maps are actually dry for much of the year. Even a major, interior basin river like the Zayandeh, which flows through Esfahan, does not reach its terminal basin for much of the year.



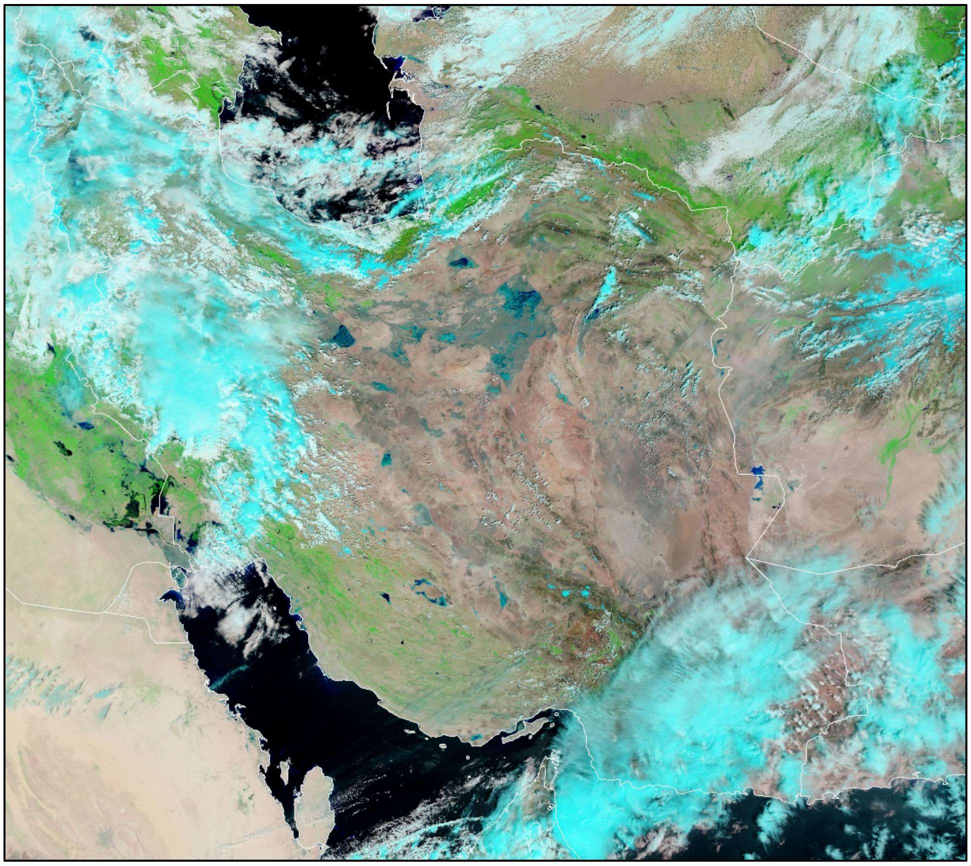
Caspian Sea shore, showing effect of rainfall on vegetation, and by implication watersheds, compared with the plateau
(CC0, NASA and NOAA).

Alborz Mountain range
(CC0, NASA).

A review of modern and historical floods in Iran is found in *Mazra'eh, News, Analytical and Educational Monthly*, No. 10, January 1998 at www.netiran.com/Htdocs/Clippings/DEconomy/980100XXDE05.html. Devastating floods occurred in 2001 for example, after several years of drought, in Gilan, Golestan and Khorasan provinces (*Islamic Republic News Agency*, 11 August, 14 August, 4 September 2001), and again in 2019 in Golestan, Khuzestan and Lorestan (www.bbc.com/news/world-middle-east-47837692, downloaded 7 April 2019). Golestan flooding was attributed in part to deforestation.



Floods in the marshes of Khuzestan and neighbouring Iraq, false colour image,
16 January 2004 (CC0, NASA).



Floods in Iran and Iraq, 28 March 2019, false colour image
(CC0, NASA).

Khuzestan, flood at Ahvaz, 4 October 2019
(CC BY 4.0, cropped, *Tasnim News Agency*).

Golestan floods, 21 March 2019
(Golestan province flood (in Farsi), CC BY 4.0, lightened, Mohammad Mohiemani).

Droughts occur and can be devastating for fish habitats. A number of habitats sampled by me in the 1970s have been reported as dry in recent years and some of my early fish samples are now unique. Abbaspour and Sabetraftar (2005) reviewed Iranian drought cycles and found arid conditions for 13 of the previous 23 years. Drought affected fishes in the drying of wetlands where hundreds of thousands of fish died; in Sistan 8-12,000 tons of fish were lost as the lakes dried up; in Fars fish losses were reported from the Kor River; in East Azarbayjan 174 ha of fish culture farms were damaged; and rivers draining to the Persian Gulf lost fishes including migratory species. The 2007-2008 drought effects on water resources in Ilam Province were summarised by Karimi and Alimoradi (2011). River discharges decreased significantly and water tables lowered. Karbassi *et al.* (2020) assessed the changes in Iran's drought severity from 1964 to 2014. They noted that the climate was 56.2% dry, 6.5% Mediterranean, 34.16% moderately dry and 3.1% very wet, and 30.6% of the country had a significantly decreasing standardised precipitation index. The drought years 1999-2001 were the worst in 30-40 years and resulted in a United Nations Technical Mission (see ReliefWeb, 22 August 2000, UN Office for the Coordination of Humanitarian Affairs (OCHA) at www.reliefweb.int; United Nations, 2001; Foghi, 2004), the Conservation of Iranian Wetlands Project (2011), U.S.-Iran Symposium on Wetlands (Quanrud, 2016), Kazemzadeh and Malekian (2017) and Gholamifard (2018b). Various effects were noted including the drying of 2,500 qanats in Yazd; in southern Fars groundwater became saline; 90% of the wetlands and lakes in Fars dried out including Barm-e Shur (Lake Maharlu basin), three of seven Haft Barm lakes, Barm Firuz, Lake Kaftar, Kamjan (Kor River basin), Parishan and most of Lake Arjan; the Latian, Lar and Karaj dams near Tehran had water reserves of 51 million cu m, down from 173 million cu m for the same period in the previous year and were within about 2 months of drying up; several lakes and wetlands of international importance dried out (Bakhtegan-Neyriz and surrounding wetlands, Hamun-e Saberi, south end of Hamun-e Puzak and Gav Khuni); rivers dried completely (Hirmand River and its terminal lake); the Dez and Karkheh rivers in Khuzestan were depleted by 70% in 2001; water rationing was implemented in Tehran and 30 other cities; and lower water levels in rivers that retained flow had reduced oxygen affecting fish (*Islamic Republic News Agency*, various

news reports, 2001). In East Azarbayjan, 190 ha of 220 ha used for fish breeding were useless through drought (*Islamic Republic News Agency*, 29 August 2001). Marshes south of Lake Urmia near Mahabad encompassing 30,000 ha dried up (*Islamic Republic News Agency*, 25 August 2001). Water reserves behind dams in the Khorasan provinces were depleted by 65% in 2001, the precipitation rate having declined by 40% in the period November 2000-August 2001 (*Islamic Republic News Agency*, 3 September 2001). Mousaei Sanjereheri and Rundel (2017) assessed the future of Iranian wetlands under climate change, finding Bakhtegan, Chagha Kur, Gav Khuni and Parishan would decrease in area by 2050 while Gori Gol would increase, for example. Urmia wetlands would be completely dry by 2032.

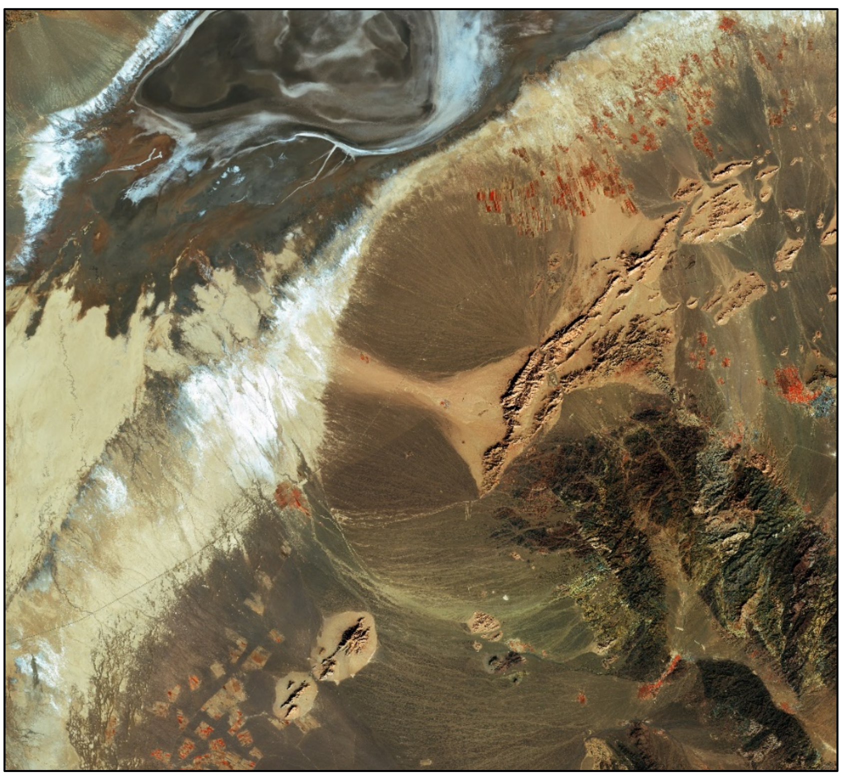
Fars, Barm Firuz Lake, 3,350 m
(Barmfiruz Lake, CC BY-SA 3.0, Omid Safiee).

Yousefi *et al*. (2020) used Iranian endemics (five cyprinids and six leuciscids, plus four other species) as proxies of their ecosystems to identify 20 high priority rivers from seven basins for conservation under climate change. Climate change was likely to lead to a reduction in range size for five species (*Acanthobrama persidis*, *Alburnoides tabarestanensis*, *Alburnus doriae*, *Capoeta buhsei* and the cobitid *Cobitis faridpaki*) while the range of ten species was likely to increase (*Alburnoides idignensis*, *Alburnoides namaki*, *Alburnoides samiii*, *Barbus miliaris*, *Capoeta aculeata*, *Carasobarbus sublimus*, *Garra persica*, the sisorid catfish *Glyptothorax silviae*, the cichlid *Iranocichla hormuzensis* and the goby *Ponticola iranicus*). Loss of suitable habitat would be more pronounced for *Cobitis faridpaki* and *Alburnoides tabarestanensis* compared to *Acanthobrama persidis*, *Alburnus doriae* and *Capoeta buhsei*. Generally, annual precipitation had the highest contribution in determining the distribution of the 15 species and temperature seasonality was the second most influential. *Acanthobrama persidis* and *Alburnus doriae* were predicted to lose their low elevation habitats and *Capoeta buhsei*, *Alburnoides tabarestanensis* and *Cobitis faridpaki* would lose their low, mid and high elevation habitats. In contrast, large areas of mid and high elevation habitat would become suitable over the next few decades for *Alburnoides idignensis*, *Alburnoides namaki*, *Alburnoides samiii*, *Barbus miliaris*, *Capoeta aculeata*, *Carasobarbus sublimus*, *Garra persica*, *Glyptothorax silviae*, *Iranocichla hormuzensis* and *Ponticola iranicus*.

The nature of the drainages of Iran is directly related to climate. The Alborz Mountains in the north block movement of moisture to the south while the Zagros Mountains in the west block moisture from that direction. The southeast monsoon is almost completely dry before it reaches eastern Iran. In consequence, the best-watered parts of Iran lie on its northern and western fringes and the interior becomes drier from west to east and north to south. Interior rivers exist in large part because of mountain ranges that store water as snow, in the case of the Hirmand River and the Sistan lakes, far removed from Iran.

There have been many studies on past climates in Iran and neighbouring countries, attempting to link climate with past environmental conditions in the Late Pleistocene-Holocene. The Early to Middle Pleistocene, however, is practically unknown for the Middle East and is not

dealt with here (Butzer, 1978). Past environments have significance for fish habitats, distributions and zoogeography. The brief summary below is based on Butzer (1957, 1958a, 1958b, 1961, 1975, 1978), Bobek (1959), Whyte (1961), Hutchinson and Cowgill (1963), van Zeist and Wright (1963), van Zeist (1967), Wright *et al*. (1967), Krinsley (1970), Diester-Haass (1973), Turnbull and Reed (1974), Nützel (1976), van Zeist and Bottema (1977, 1982), Wright (1977, 1983), Ganji (1978), Neumann and Sigrist (1978), van Zeist and Woldring (1978), Woosley and Hole (1978), Farrand (1979), Storch (1980), Coad (1980b), Kay and Johnson (1981), Lamb (1982), Neumann (1993), Qin and Yu (1998), Griffiths *et al*. (2001), Stevens *et al*. (2001), Snyder *et al*. (2001); this being by no means an exhaustive listing of the studies in this field nor is the below a critical assessment of conflicting views. Evidence for these past environments is taken from a number of studies in different fields. The Pleistocene ice has been gradually withdrawing from its last maximum at 20,000 B.P. and the remains of ice fields and glacial moraines can be used to determine former conditions such as the snowline. The advance and retreat of deserts and the use and abandonment of settlements are indicative of changes. Such erosional physical features as dry riverbeds and other riverine structures, alluvial fans, sand dunes, and aeolian deposits all give clues to environmental change. The extent and level of lakes and playas have been widely studied as indicators of climatic fluctuations. Pollen and other organisms associated with lake sediments can be used to trace changing conditions, and finally historical records can be analyzed.



Razavi Khorasan, Bajestan (far right), alluvial fans centre and top left
(Iranian painting ESA363411, CC BY-SA 3.0 IGO, European Space Agency, contains modified Copernicus Sentinel data).

Glacial deposits in the outward slopes of the Zagros and Alborz mountains indicate that the snowline was 600-800 m lower than today, perhaps as much as 1,800 m in some areas, and as

much as 1,500 m at Shir Kuh near Yazd and Kuh-e Jupar near Kerman in south-central Iran. Lowered snowlines cannot be explained by temperature alone but were probably due to much greater precipitation. Winter would have been longer and colder in the Pleistocene, more snow would accumulate and summers may have been cloudier. The runoff period would have been longer and river habitats could have been less prone to desiccation in late summer.

The climate in the Zagros Mountains of the late Quaternary in Iran has been examined by means of sediment analyses from lakes Zaribar and Mirabad and for nearby Turkey at Lake Van. Pollen, chemistry, sediments, diatoms, cladocerans, ostracods and palaeobotany all confirm geological studies. The last glacial maximum (the Würm) at about 20,000 B.P. led to local glaciation, a depression in the snow line and absence of trees. The climate was cool and relatively dry, with less precipitation than today. The cooler temperatures meant less evaporation, more runoff and filling of intermontane lakes. The Caspian Sea and Lake Urmia were much larger than today, being 78 m and 55 m higher. As the glaciers receded, the land environment or life zones moved up the mountains. The significance of this for fishes is unknown; there were few trees and the environment may have resembled modern denuded conditions. There may have been a higher flow than later when trees developed to hold runoff and before man chopped them down. However, bushes could have retained water and reduced silt load in rivers. By 12-14,000 B.P the evidence from Zaribar and Mirabad indicated a warming climate but without increased precipitation. Indeed, rainfall may have been less than today, reducing river flows and perhaps habitats for fishes. This arid period was succeeded by a more humid period. An increase in precipitation at Lake Van did not take place until 6,500 B.P., about 4,000 years later than in western Iran. Climate changed not only through time but also geographically, just as today. Regional variations mask general statements about earlier climate for Iran and the outline given here is perhaps best seen as indicative that change occurred. The humid period was followed by a period of less rainfall, and then in the late Holocene by an increase in rainfall. The last 3,000 years have been humid with perhaps two, short, arid episodes. Southern Iran may have been cool and comparatively moist when the highlands were moderately cold and relatively dry. Climate probably changed markedly over short periods. Short cold phases are recorded for Europe in the last several thousand years, e.g., from about 1400 to 1230 B.C., associated with rises in lake levels. Similar events may have occurred in Iran. Barley harvest dates in Babylonia derived from clay tablets indicate they were 10-20 days earlier in the period 1800-1650 B.C. and 10-20 days later in 600-400 B.C. It is concluded that the former period was warmer and the latter cooler than today.

Pluvial conditions as recognised for the more northerly areas of Europe probably did not occur in Iran during the Pleistocene although summers may have been less dry because of greater cloudiness and lower temperatures and evaporation. Lake levels were probably higher 18,000-20,000 years ago (Roberts and Wright, 1993). Krinsley (1970), in his study of playas in Iran, concluded that the climate was semi-arid rather than pluvial in the period of maximum cold during the Pleistocene. Lakes, which occupied endorheic basins and could have facilitated local fish movements, dried up as the climate warmed with the retreat of ice sheets and glaciers and evaporation exceeded precipitation. These shallow lakes were found along the inner mountain front or within basins that received greater discharges. As distance from the mountains increased, there were only intermittent lakes and finally playas. An immense lake filling much of central Iran, as proposed by earlier authors, seems unlikely. Generally, conditions over Iran appear to have varied as much, if not more, in the Pleistocene as they did in recent centuries through the agency of man. Conditions 9,000 years ago were probably drier than today (Roberts and Wright,

1993). The fishes may have been selected for an ability to survive highly variable conditions in terms of stream flow, temperature, silt load, local fluctuations in lake levels and salt content, etc.

A greenhouse effect is apparent in Iran, a rise in temperature caused by various man-made and released gases. Nasrallah and Balling (1993) showed a temperature increase of 0.09-0.23C°/decade, mean 0.18C°/decade, from 1950-1990.

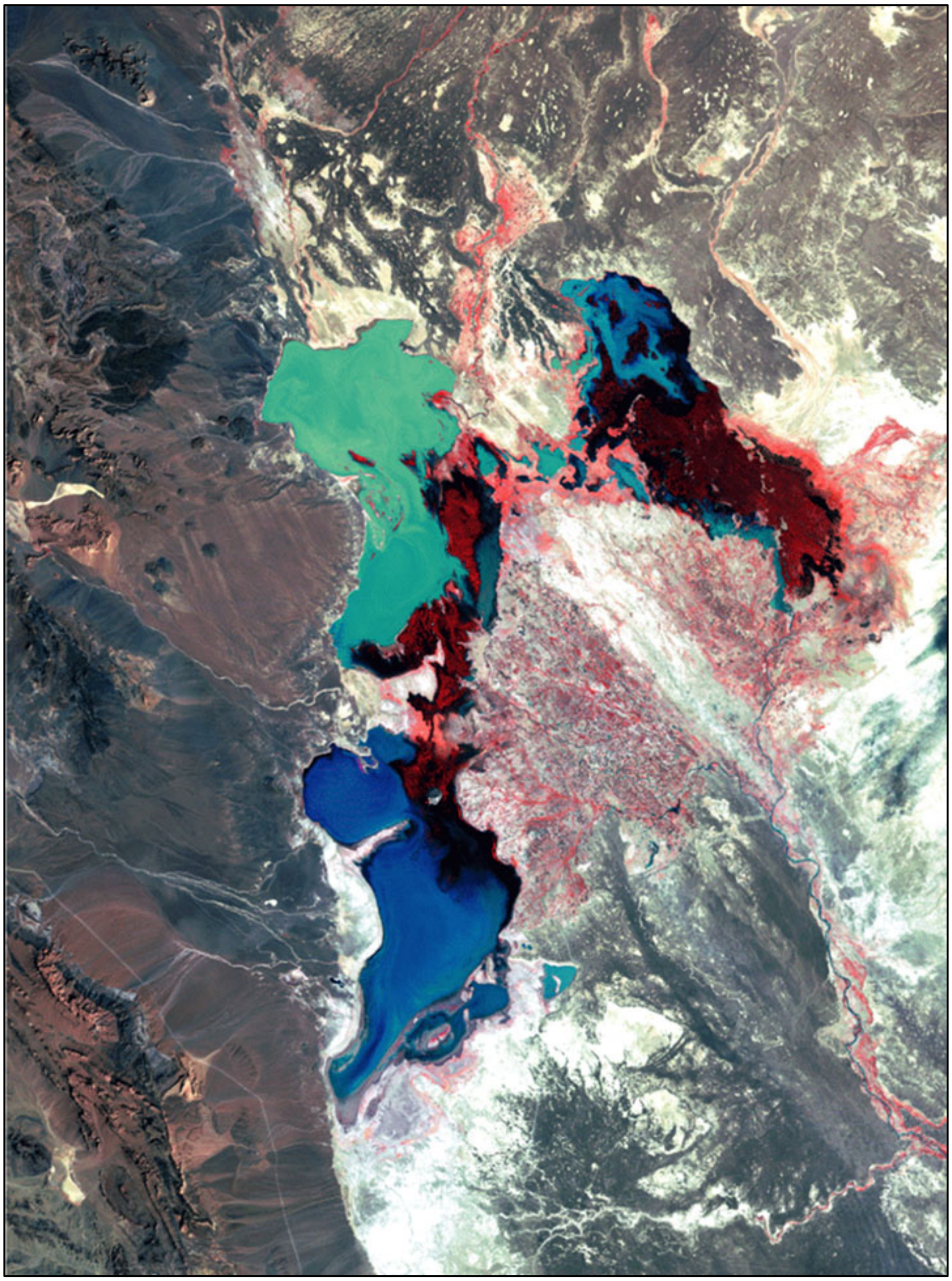
**Habitats**

The major rivers of Iran drain the two mountain chains which retain enough snow or collect enough rainfall to ensure a constant and appreciable flow. Afshin (1994) summarised the rivers of Iran. All rivers in Iran are fordable on foot when not in spring flood with the exception of the Aras and Sefid rivers of the Caspian basin, the Hirmand river of Sistan and the large rivers of Khuzestan. Most rivers marked on maps are in reality small streams, with very shallow and clear water. There is little vegetation on the banks, and fishes, if present, can be seen with ease. A significant proportion of fish habitat is occupied by small streams, springs and qanats. There are 8,193 springs in Iran (Encyclopædia Iranica, www.iranicaonline.org/, downloaded 10 July 2016). Large freshwater lakes or marshes are absent except in Sistan, the Caspian basin and the plains of Khuzestan. Most large lakes on maps are salty and do not support a fish fauna. A large number of dams have been built and more are planned (see Bagley (1976), Coad (1980b) and *Aquastat* from the Food and Agriculture Organization, Rome (www.fao.org/ag/agl/aglw/aquastat/iran.htm), and Wikipedia) and these form important lacustrine habitats. In 1994, 27 storage dams were in operation with a capacity of 39.2 cu km and a further 24 were under construction with a capacity of 11.5 cu km (see also below for more on dams). In 2002 Iran was building 68 dams and the construction of a further 120 dams were being considered as 33% of the country's water resources were wasted (*Islamic Republic News Agency*, 2 January 2002). Manouchehri and Mahmoodian (2002) briefly reviewed environmental impacts of dams in Iran and more extensive treatments are in Najmaii (2004) and Zafarnejad (2009).

The streams may have their origin in a mountain, a spring or a qanat, but they hold in common clarity of water, a bare pebble bed, small dimensions (one to a few metres wide and a few centimetres deep) and often a short course. They may join another stream but are often lost in marshes, tapped for irrigation and lost in fields or become absorbed by the friable and porous ground. Many streams are intermittent, with flow near their mountain source, dry sections and perhaps a flow near their mid-course, with subsequent absorption into the ground. Heavy aquatic vegetation is not common and most plant material is a thin encrusting layer on the bottom. Banks are often bare of riparian vegetation and streams are fully exposed to insolation. Summer temperatures are often high as a result (30°C and more) yet at higher altitudes streams can be icy cold even in summer and the typical blue-grey of snow-fed water. Spring floods can be disastrous, scouring out the stream beds and dumping heavy silt loads (Melville, 1984). Spring fed streams of shorter course are not affected because they have a small catchment area and may well provide a refuge for fishes. The clean water of springs attracts human settlement and these waters are often blocked off to form ponds or cisterns with water led off through artificial channels subject to drying as requirements change. Streams and rivers may also be impounded, forming small ponds or lakes. Bridges often have small pools beneath them and this may be the deepest (at ca. 1 m) and most shaded section of a stream.

Marsh areas may be associated with springs. Reeds and other vegetation develop downstream of the source and may be quite extensive, occupying several square kilometres.

Some areas of marsh are ponded and provide habitat for larger species as well as shelter for young. Extensive marshes, lakes and lagoons are developed in Sistan, the Caspian basin and Khuzestan; all fed by major rivers (50+ m wide and 3+ m deep) draining vast areas of land. These areas vary widely with season and flood dramatically in spring, inundating vast tracts of land. The rivers and associated marsh-lake complexes provide the major freshwater food fishing areas in Iran. The Sistan marshes have been described in Annandale (1921) and Annandale and Hora (1920), the Caspian shore by Schüz (1959) and the lowlands of southern Iraq by Rzóska (1980) and by Thesiger (1985) and Young (1989).



Sistan marshes, 1976, reed beds dark red, half metre deep water light blue, up to 4 metres deep water dark blue to black, false colour (CC0, NASA).

Environmental challenges and conservation of aquatic habitats, and therefore fish biodiversity, in Iran have been part of a general programme for biotic conservation summarised in Firouz (1974, 1976), Firouz and Harrington (1976), Ashtiani-Zarandi (1990), Kahrom (2000), Jowkar *et al*. (2016) and Tahbaz (2016). In particular a fast-growing population and so increased human activity, as well as aridification, agricultural demands for water (more than 90% of water usage), pollution, invasive species and climate change are factors affecting biodiversity. Balali *et al*. (2019) discussed the effect of climate change on rainfall and consequent effects on aquaculture and fisheries. Shahni Danesh *et al*. (2016) found in Iran temperature increased evaporation and decreased runoff, but caused increased runoff in winter and a decrease in spring Water demands have resulted in schemes for interbasin water transfers in Iran which are reviewed by Abrishamchi and Tajrishy (2005) and appear generally in the text below. Such transfers can transport endemics and other fishes from one basin to another.

Water management in Iran was reviewed by Madani (2014), Madani *et al*. (2016) and Tahbaz (2016) who recognised several major causes for a water crisis, namely rapid population growth and inappropriate spatial population distribution, environmental unawareness, improper water governance, an inefficient agriculture sector, dam construction leading to loss of wetlands and lakes, pollution, over-abstraction of surface and groundwater, droughts, flash floods, climate change, and mismanagement and a thirst for development. Amiri and Eslamian (2010) also noted adverse effects of climate change on water resources and drought frequency. Salmanmahine and Safidiyan (2013) assessed the hydrological vulnerability of International Wetlands in Iran. Makhdoum (2014) gave an overview of the state of the environment in Iran noting the eradication of major wetlands, dysfunction of water tables, shortage of water and water misuse in agricultural practices.

The Ramsar Convention on Wetlands of International Importance was named after the city of Ramsar in northern Iran where the first conference was held in January 1971. Iran has more Ramsar listed sites than any other country in Southwest Asia (Scott, 1993). In 1977 there were 11 Park-e Melli (National Parks), 4 Asar-e Tabii Melli (National Nature Monuments), 24 Manatgheh-Hefazat Shodeh (Protected Regions or Areas) and 31 Panahgah-e hayat-e Vahsh (Wildlife Refuges) offering varying degrees of protection to the fish fauna (Firouz *et al*., 1970; Yachkaschi, 1976; Köpp and Yachkaschi, 1978; Majnunian, 1985). The 1993 United Nations List of National Parks and Protected Areas at www.wcmc.org.uk/data/database/un_combo.html listed seven National Parks, two National Nature Monuments, 41 Protected Areas and 18 Wildlife Refuges and the *National Report of the Islamic Republic of Iran for the Convention on Biological Diversity* (Department of the Environment, Tehran) listed 11 National Parks, 47 Protected Areas, 25 Wildlife Refuges, five National Nature Monuments, nine MAB (Man and Biosphere) Sites and 20 Ramsar Sites. The Ramsar Sites Information Service listed 25 Ramsar Sites (www.ramsar.org/, downloaded 7 March 2019). Kolahi *et al*. (2013) listed 26 National Parks, 35 National Natural Monuments, 42 Wildlife Refuges and 150 Protected Areas, comprising 16,676,734 ha or 10.12% of the whole country. Seyed-Emami and Ashayeri (2016) gave an overview of national parks in Iran and their relationship to local people which impinges on their effectiveness, and consequently on fish conservation.

Seven Ramsar sites are priorities for urgent action with the causes, namely:- Alagol, Ulmogol and Ajigol lakes (impact of agricultural development), the Anzali Talab complex (falling water levels and increased eutrophication leading to the rapid spread of the reed *Phragmites australis*), south end of Hamun-e Puzak (water inflow could be reduced because of dam construction in Afghanistan), Hamun-e Saberi and Hamun-e Hirmand (dam construction in

Afghanistan), Neyriz lakes and Kamjan Marshes (drought and agricultural activities), Shadegan Marshes and mudflats of Khor al Amaya and Khor Musa (chemical pollution from the Iran-Iraq war), and Shur Gol, Yadegarlu and Dorgeh Sangi lakes (war and drought effects) (www.ramsar.org/ram_rpt_37e.htm, downloaded 28 July 2000).

The status of the fish fauna in Iran was assessed by Coad (1980b) and Kiabi *et al*. (1999) and compared with other areas by Moyle and Leidy in Fiedler and Jain (1992). The percentage of the total fauna under some form of threat was assessed at 22%, a figure which was lower than most other areas examined. The IUCN (2015; https://newredlist.iucnredlist.org/, downloaded 15 October 2018; check for updates) assessments are given below for the species over their whole distribution. Apart from Iranian endemics and species found mostly in Iran and adjacent countries, these assessments may not depend much on Iranian data. Given human population increases and agricultural, domestic and industrial demands for water, pollution and drought in Iran however, these assessments probably apply to Iran and may be conservative. Cyprinid fish assessments follow and species not included have no assessment.

Critically Endangered: *Luciobarbus subquincunciatus*
Vulnerable: *Arabibarbus grypus*, *Carasobarbus kosswigi*, *Cyprinus carpio*, *Luciobarbus capito*, *Luciobarbus caspius*, *Luciobarbus esocinus*, *Luciobarbus xanthopterus*, *Mesopotamichthys sharpeyi*
Least Concern: *Bangana dero*, *Barbus lacerta*, *Capoeta buhsei*, *Capoeta trutta*, *Capoeta umbla*, *Carasobarbus luteus*, *Cyprinion kais*, *Cyprinion macrostomus*, *Cyprinion watsoni*, *Garra rufa*, *Garra variabilis*, *Luciobarbus mursa*, *Schizocypris altidorsalis*, *Schizothorax pelzami*
Data Deficient: *Luciobarbus kersin*

Note that *Luciobarbus caspius* is covered under *L. brachycephalus* as it was the Caspian Sea subspecies. As such it is listed as Vulnerable.

Iran has several unusual habitats for fishes and these are described below.

i) Hot springs

A number of hot springs are reported from Iran (Waring, 1965; Joneidi *et al*., 1971; www.bibliothecapersica.com/articlenavigation/index.html, under ab-e garm, downloaded 24 December 2004). Some of the hot springs marked on maps are not hot, e.g., the spring at Tafresh (ca. 34°44'N, 50°02'E) was only 19°C (and fishless). Some springs produce water at relatively high temperatures, but since these temperatures are also seen in nearby streams they are not regarded as "hot", e.g., a spring near Farrashband (28°53'N, 52°06'E) at 30°C (CMNFI 1979-0129, 24 November 1976).

The Sartang-e Bijar hot spring at Mehran, Ilam in the Tigris River drainage (33°46'16.3"N 45°56'17.2"E) is the type locality for *Garra amirhosseini*, *q.v*.

The hot spring at Genu (27º26'N, 56º20'E) contains fish including the cyprinids *Cyprinion watsoni* and *Garra persica* (Coad, 1980b). The Ab-e Garm (literally hot water) at Genu emerges at 41°C and was partially enclosed by brickwork associated with a hammam or bath-house. The altitude of the spring is about 400 m. Its stream is 10-15 m wide near the source and the bed is composed of stones and pebbles covered by lime-green algal mats and strings. Only *Aphaniops ginaonis* (the eponymous aphaniid) was found at the hot spring, not in the main flow but along the stream margins and in many minor subsidiary springs which emerge a few

metres from the main spring. These minor springs had a mud bottom, were as shallow as 1 cm and had soap and food debris pollution in 1977. Side springs and stream margin near the source were 37-40ºC. The other species (along with *A. ginaonis*) were found below a cascade and have no access to the hotter parts of the spring and stream. The water is clear and colourless, but there is a strong smell of sulphur. Flow is 30 l/sec. The chemistry of this spring as given by Joneidi *et al*. (1971) was:- pH = 6.2, conductivity 14,000 us (*sic*), dry residue at 180ºC = 9,933 mg/l, $H_2S$ = 34 (presumably p.p.b.), r (reacting value) Ca = 22.4, r Mg = 9.9, r Na + K = 6.1, total cations 162.1 (*sic*), r Cl = 147, r $SO_4$ = 15.4, r $HCO_3$ = 4.6, total anions = 166 (*sic*), $SiO_2$ = 10 mg/l, $NH_4$ = 0.7 (no units given), $NO_3$ = 22 (no units given). There were traces of $CO_2$ and no measurable Fe, $NO_2$, or $CO_3$. The hot spring lies in the Genu Protected Area (Biosphere Reserve) which is described by Zehzad *et al*. (1997) and Bakhtiari (2020b).

Habitat of *Cyprinion watsoni* and *Garra persica*, Hormozgan, Ganow Hot Spring, 27 January 1977, Brian W. Coad.

ii) Caves

Iran is replete with caves and underground habitats but thus far only three have been found to contain a fish fauna. One cave lies about 12 km north of the railway station Tang-e Haft in Lorestan at 33°05'N, 48°36'E (Google Maps has this cave in Khuzestan). Three species are found here, *Garra* (formerly *Iranocypris*) *typhlops*, *Garra lorestanensis* and *Eidinemacheilus smithi* (Nemacheilidae) (Bruun and Kaiser, 1944; Movaghar, 1973; Greenwood, 1976; Smith, 1978, 1979; Coad, 1996b; Proudlove, 2001; Romero and Paulson, 2001; Sargeran *et al*., 2008; Farashi *et al*., 2014). The cave lies in the Dez River drainage of the Tigris River basin and its connection to nearby surface water is intermittent. The cave is the surface outlet of a subterranean limestone system and the captures may represent strays from underground. B. Sandford (pers. comm., 1979) stated that there is some evidence of recent collapse in the cave system and thus the habitat may be endangered but it is difficult to assess the extent and nature of underground fissures in the rock. Cave fishes are now known also from some springs and so are probably widely distributed in karst environments (see under *Garra lorestanensis*).

Lorestan, Sezar River exiting Tang-e Haft, 4 December 2000, Brian W. Coad.

Lorestan, Loven Cave, A. H. Zalaghi.

A second underground locality is at a dam tunnel now sealed in concrete and inaccessible (see Mahjoorazad and Coad (2009) and Coad (2019b) for details and under the introduction to the genus *Garra*). A third cave locality is at Tashan in southern Khuzestan (and see under the description of *Garra tashanensis*).

Khuzestan, entrance of Tashan Cave, from R. F. Motlagh and Eslam Baderi,
via Jalal Valiallahi, 2016.

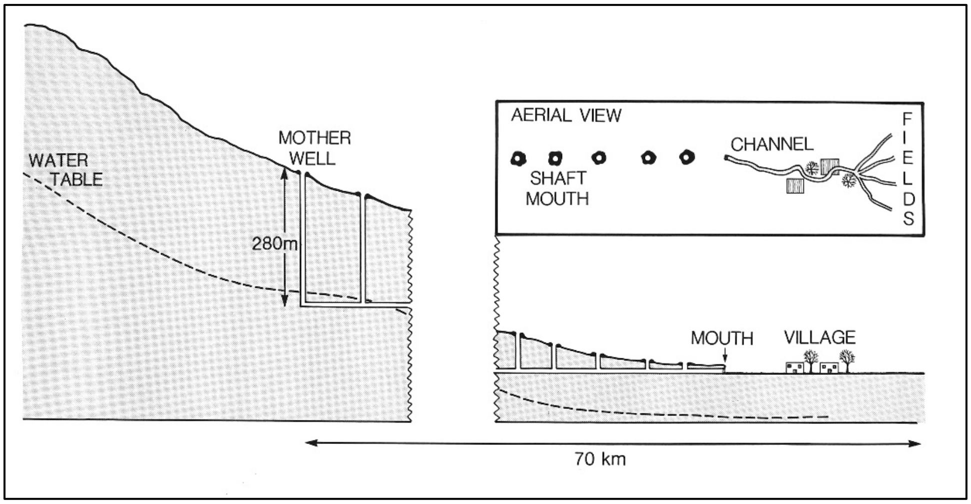

Khuzestan, Tashan Cave, from R. F. Motlagh and Eslam Baderi, via Jalal Valiallahi, 2016.

iii) Qanats

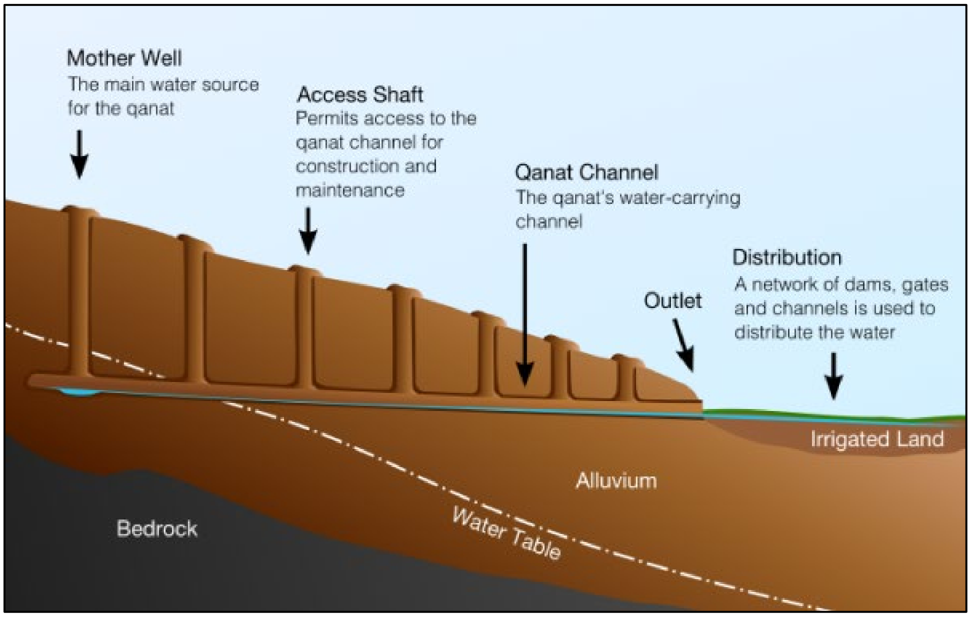
Qanats are an unusual yet important habitat for fishes in Iran. An account of their fishes with an extensive bibliography was given in Coad (1996f); additional literature on this unique environment not referenced there includes Kuros (1943), Aisenstein (1947), Feylessoufi (1959), Nesbitt and Bawa (1960, 1961), de Menasce (1966), Jentsch (1970), Nadji (1970, 1972a, 1972b), Braun (1974), Goblot (1979), Hartl (1979), Honari (1979), Sajjadi (1982), Goldsmith and Hildyard (1984), Behnia (1988, 2000), McLachlan (1988), Beaumont *et al*. (1989), Harwit (1990), Razavi (1991), Coad (1994b), Koocheki (1996), Liaqati (1997), Salim Manshadi *et al*. (1997), Afkhami (1998), English (1998), Farshad and Zinck (1998), Aminpouri (2002), www.netiran.com/Htdocs/Clippings/DEconomy/200629XXDE05.html, downloaded 8 August 2002, Foltz (2002), Floor (2003), Wessels and Hoogeveen (2003), Esmaeili *et al*. (2006), Zaker Hosseini *et al*. (2007), Rezaei Tavabe and Azarnivand (2008), Jomehpour (2009), Marjanizadeh *et al*. (2009), Semsar Yazdi and Labbaf Khaneiki (2010), Taghavi-Jeloudar *et al*. (2013), Akhani (2015), Yazdi and Khaneiki (2018) and qanats at www.waterhistory.org, and at www.bibliothecapersica.com/articlenavigation/index.html, under abyari (irrigation), downloaded 24 December 2004. Extensive material is also now available on the internet.

There is an "International Center on Qanats and Historic Hydraulic Structures" with a website at http://icqhs.org/ under the auspices of UNESCO which contains more data on qanats and their study. The Persian qanat is a UNESCO World Heritage Site (specifically listed as those in Razavi Khorasan, South Khorasan, Yazd, Kerman, Markazi and Esfahan provinces although of course they occur in other provinces too). The qanats at Gonabad in particular, built between 700 and 500 BCE by the Achaemenid Empire, contain 427 water wells with a total length of 33,113 metres (20.575 mi). The site was first added to UNESCO's list of tentative World

Heritage Sites in 2007, then officially inscribed in 2016, collectively with several other qanats, as "The Persian Qanat".



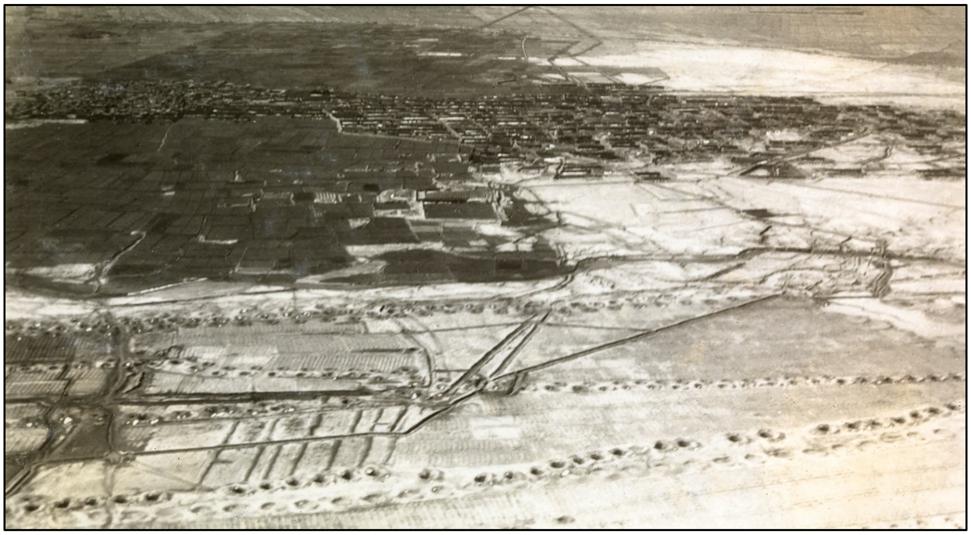

Qanat diagram, Susan Laurie-Bourque @ Canadian Museum of Nature.




Qanat cross section
(CC BY 3.0, Samuel Bailey).

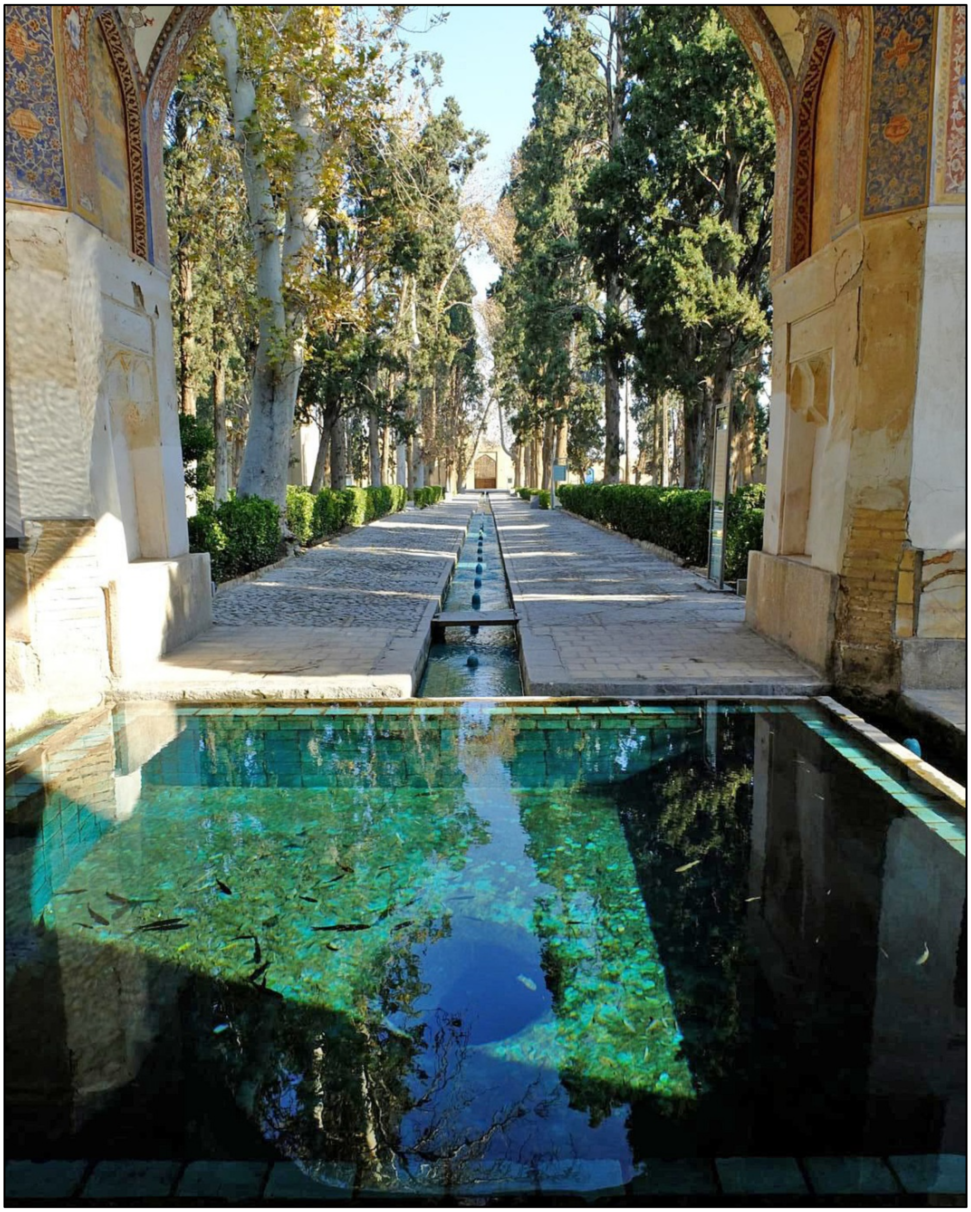

Iranian stamp showing qanat cross-section, a windlass and access shafts, Brian W. Coad.

Kerman, qanat access shaft with other shafts in distance
(CC BY-SA 4.0, cropped, Ziegler175).



Esfahan, qanat access shaft mouths at Kashan, February 1925
(CC0, cropped and sharpened, ETH-Bibliothek, Walter Mittelholzer).

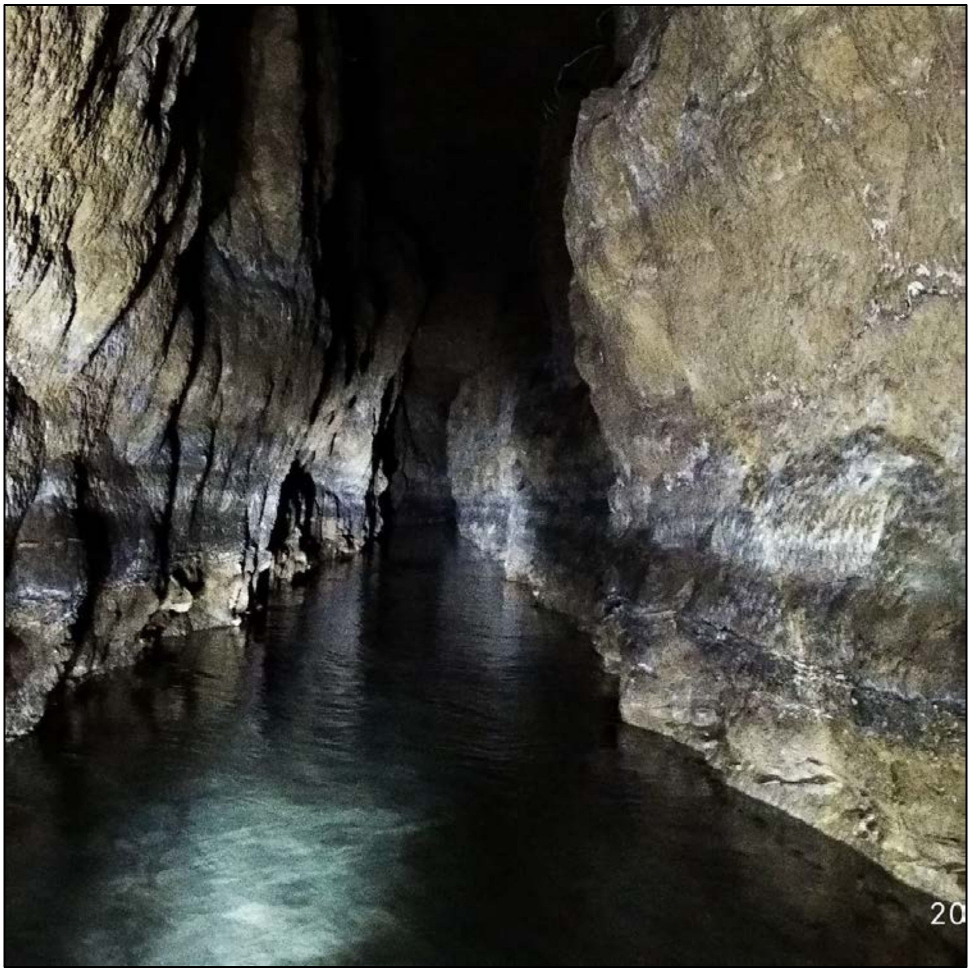
Esfahan, qanat and pool at Kashan
(Qanat Kashan, CC BY-SA 3.0, Zereshk).



Esfahan, Bagh-e Fin, Kashan
(Finn bagh kashan 2013-3, CC BY 2.0, lightened, Franco Pecchio).

Habitat of *Capoeta saadii*, CMNFI 1979-0043, Fars, qanat mouth at Sarvestan, water temperature 25ºC, 10 March 1976, Brian W. Coad.

Habitat of *Alburnus sellal* and *Capoeta saadii*, CMNFI 1979-0067, Fars, qanat at Zarqan, 27 April 1976, Brian W. Coad.




Razavi Khorasan, inside a qanat at Gonabad,
(Kariz Gonabad, CC BY-SA 4.0, Basp1).

Razavi Khorasan, inside a qanat at Gonabad,
(Kariz kaykhosrow, CCO 1.0, lightened, Morteza Lal).

The word qanat has various suggested origins including a derivation from the Akkadian for reed according to Goblot (1979) in contrast to others listed in Coad (1996f).

Over 20% of the irrigated area of Iran was fed by qanats (Redding and Midlen, 1991) and numbers as high as 60,000 have been estimated. They are essentially horizontal wells which tap groundwater and provide a continual, low gradient flow of fresh water. Qanats are an advantageous habitat for fishes in several ways. The water temperature is not subject to the extremes found in natural waters, shade within the qanat provides protection against predators on adults, young and eggs and against insolation, the gradient and water flow are gentle, and a certain amount of food is provided by kitchen scraps since dishes, cooking containers and implements are washed in the jube or irrigation channel (see below), and food is cleaned and trimmed there. A school of fish will quickly gather at a washing site and maintain station in clouds of detergent in order to pick up scraps of food. Attempts to imitate washing movements will attract fish momentarily but they soon dart off when no food is forthcoming. The garden environment with trees and other vegetation provides shade, energy input from leaf fall and garbage items, and facilitates development of an invertebrate fauna as a food source. Aufwuchs on rock surfaces provide a food source along with the associated invertebrate fauna. The Zoroastrian community, once widespread in Iran, has a ceremony known as *com-e mahi* (= meal for the fishes) in which bread and dried fruit are thrown into running water as a libation (Boyce, 1977). Feeding of scraps to fish is also seen in Moslem communities and boys regularly attempt to attract and catch fish using any available food material and primitive fishing gear (personal observations; Edwards, 1971). Rezaei Tavabe and Azarnivand (2008) noted that fish are caught for food by local people from qanats of Kerman Township but the restricted size of the habitat means they are not a significant dietary item.

Qanats are rapidly being replaced by pump-wells which are faster and easier to excavate

but do not provide fish habitat. Pump-wells often dry up qanats and natural springs by lowering the water table (Razavi, 1991; Anonymous, 2001a; Aminpouri, 2002). Also schemes to restrict water flow from qanats for conservation reasons will presumably affect the available habitat for fishes (Salim Manshadi *et al*., 1997).

The qanat fishes comprised 25 species in Coad's study (1996f), 40% of the fauna on the plateau of Iran. Cyprinoids found in qanats number at least 23 species, allowing for recent revisions and descriptions of new taxa (Esmaeili *et al*., 2006). The number of species per qanat ranges from one to six although 88% of qanats have only 1-2 species. Areas with little surface water and low in diversity have 94% of the species occurring in qanats while better-watered areas with more diversity have only 29% of species in qanats. The qanat fauna is dominated by the Cyprinoidei, which comprises 76% of the ichthyofauna. The qanat fauna is a subset of the basin in which the qanat occurs, comprising small species, broadcast spawners, lacking in specialised food requirements (usually scrapers of aufwuchs or feeding on invertebrates), non-migratory, and widely tolerant of environmental conditions.

Rezaei Tavabe and Azarnivand (2008, 2013) gave hydrological information on 27 qanats in Kerman County, southeast Iran. Qanat length ranged from 200 m to 11,000 m and discharge from 3 l/s to 243 l/s. Sulphate was 0.3-9.1, sodium 0.4-5.3, magnesium 0.4-4.3, calcium 1.7-8.0, chloride 0.6-1.8, bicarbonate 1.0-3.2 and total dissolved solids 375-947 (all p.p.m.) and pH was 7.4-7.9. Species identified included *Gambusia affinis* (probably *G. holbrooki*, eastern mosquitofish, introduced) and the cyprinoids *Alburnoides bipunctatus* (possibly *A. eichwaldii* or some other Caspian Sea basin species, presumably introduced, if correctly identified to genus), *Capoeta aculeata*, *Capoeta damascina* (*sic*, presumably *C. saadii*), *Capoeta fusca*, *Garra persica* and *Pseudorasbora parva* (introduced). The records of *C. aculeata* and *C. fusca* are probably in error unless these species are translocations.

In the seventeenth century qanat fishes "were not esteemed as they never saw the light and were used only for medicinal purposes to cause vomiting" (Ferrier, 1996, quoting Jean Chardin). In the 1950s villagers in Iran believed that qanat fish lived forever and needed no food, only their own eggs (www.iras.ucalgary.ca/~volk/sylvia/qanat.htm, downloaded 24 June 2002).

Colonisation is both natural, since brook loaches (Nemacheilidae) are unlikely to be seen and caught by local people, and deliberate since larger cyprinoids are found in qanats remote from any surface water. These fish are hardy, already living in high temperature environments, and are easily transported for Now Ruz celebrations. At the Zard-Abieh qanat in Shahrud, a local man remembered putting fish into the qanat 60 years ago from one now dry (H. Rahimian, pers. comm., 2000).

The jube is an artificial channel or irrigation ditch flowing in the open air, distributing water from a qanat, from a spring, or from a river as a take-off from higher up to irrigate land above an incised river bed lower down the river valley. In the countryside, an unknown source of a jube may be kilometres away from the sample site where fish were caught, and so jube is the term used to indicate the habitat type.

Fars, village jube, 25 November 1976, Brian W. Coad.

iv) Salt streams and lakes

Salt lakes are common in Iran and are mostly too saline to support a fish fauna. They are discussed in a world context by Williams (1996). Fishes do exist in tributary streams (which may be saline in varying degrees). Rivers and springs around salt lakes are therefore isolated from one another and might be expected to give rise to unique populations of fishes. However, all these salt lakes are shallow and liable to desiccate such that tributary streams and springs can connect and allow faunal interchanges once the lake level falls.

Many streams in Iran are highly mineralized or even salt to taste yet these support fishes which are usually regarded, at least at the family level, as salt intolerant. Salinity tolerance studies have not been carried out on many Iranian fishes. The Caspian Sea is at one-third sea water (12-13‰) yet typical “fresh” water species can be found there, e.g., *Cyprinus carpio*.

Habitat of *Cyprinion watsoni* and *Garra rossica*, CMNFI 1979-0338/0339, Baluchestan, Tahlab River near Mirjaveh, rimed with salt, 8 December 1977, Brian W. Coad.

CMNFI 2008-0174, Khuzestan, salt stream south of Shushtar (no cyprinoids, only the aphaniid *Aphaniops dispar*), 30 November 2000, Brian W. Coad.

Hormozgan, salt river with salt dome behind near Bandar Abbas, too salty for cyprinoids, 28 January 1977, Brian W. Coad.

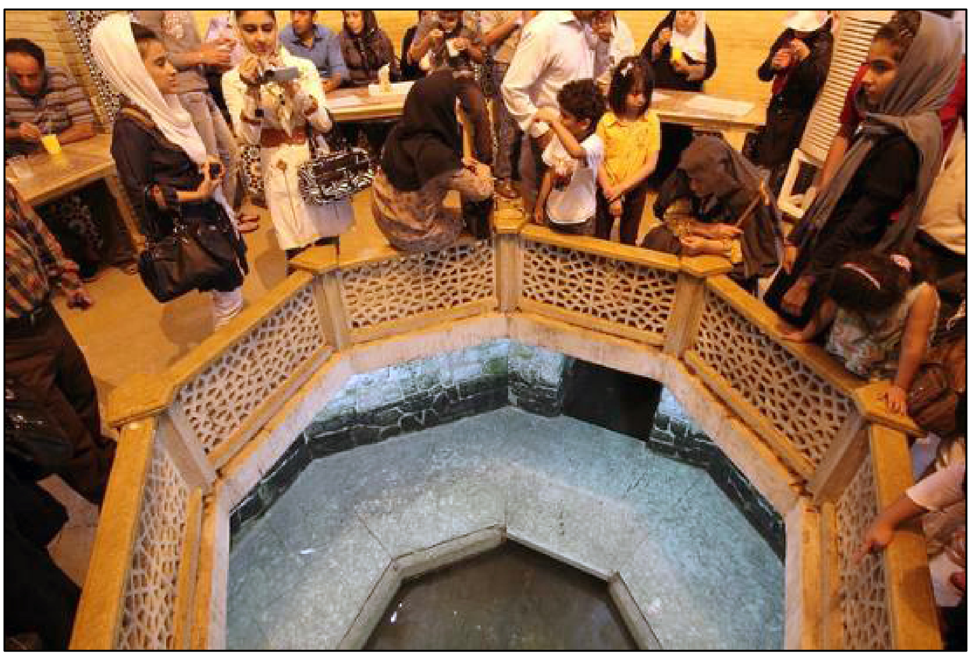
v) Sacred waters

A number of springs in Iran are said to be “sacred” and their fish then attain a degree of importance on account of their inaccessibility to ichthyologists. Howz or tanks at Qumisheh (=

Shahreza) (32°01'N, 51°52'E) were supposed to hold sacred fish, decorated with gold rings, according to John Fryer in 1698 and John Chardin in 1711, but G. N. Curzon in 1892 mentioned that the gold rings were gone and by 1978 so were the fish. A sacred tank or artificial reservoir at Soh contained fish deemed to be holy. Visitors were expected to purchase bread to feed these fishes (Anderson, 1880).

The most important "sacred" fish are those of Sa`di's Tomb in Shiraz (29°37'N, 52°35'E) which were described by Heckel (1847b) as new species *Scaphiodon saadii* (= *Capoeta saadii*) and *Discognathus crenulatus* (= *Garra rufa*). The water is a qanat under the tomb and part is expanded into a hawz-e mahi or fish pond. Fish have been present here since at least the early nineteenth century as they are mentioned briefly by Waring (1807). Morier (1818) did not see any fish on his visit. Official permission was gained to collect fishes in Sa`di's Tomb for study but sampling was actively discouraged by local people. Sa`di was supposed to punish any killing of these fishes with death but the traveler Chardin (1686) was able to catch some to eat by monetary means. Some of these fish too were reputedly decorated with gold rings (Ouseley, 1819-1823); regrettably my captures were not. Javadi and Arabsolghar (2013) discussed the perception of the "purity" of the water in Sa`di's Tomb and thence the fishes and Coad (2015e) described the locality and its fishes. The habitat temperature was consistently 22°C, conductivity was 0.66 millimhos, sulphate was 175-180 p.p.m., $CaCO_3$ was 280-300 p.p.m., $NO_3$ was 40 p.p.m., and oxygen 9.0 ml/l. Conditions seemed relatively stable over all four collecting periods despite variations in ambient weather (14 March, 25 April, 23 June and 24 June 1976). The bottom consisted of bedrock, gravel, pebbles, sand and some mud. The water level varied with a concrete shelf flooded at some times and not at others. The fish may be pale but were not depigmented like cave fishes. The sun reached the water surface for part of the day and encrusting algae were present. The Pool of Wishes (Williams, 1907) and upper reaches of the stream (Brian W. Coad, 1976 visits) were accessible and open to the air and historically were used for domestic purposes, allowing input of kitchen wastes. Bread scraps were also fed to the fish.

Fars, Sa`di’s Tomb in Shiraz
(Saadi Tomb, CC0, Omid Hatami).



Fars, Sa`di’s Tomb in Shiraz, Pool of Wishes public gallery (after Coad, 2015d).

Fars, Sa`di’s Tomb in Shiraz, Pool of Wishes (after Coad, 2015d).
Note that there appears to be a goldfish (*Carassius auratus*) top right
in this picture taken in August 2013.

vi) Mordab (= Talab)

A mordab is a fresh or brackish water lagoon area found along the Caspian Sea coast (literally dead water; the Russian equivalent is liman). The Anzali Mordab at 37°26'N, 49°25'E is the best known (Firouz, 1968b; Jafari, 2009; Björk, 2014) and was formerly called the Pahlavi Mordab. The more modern term is talab (= pool or marsh, which lacks the association with death) but the older literature refers to mordab. The Talab is also referred to as a lagoon or wetland in the literature and may be so cited in this text. The Anzali Talab is about 30 km long and 4-8 km wide with clear water of only 1.5 m average depth. Much of the area is covered by *Phragmites* reeds and other plants, and only about 15% is open water. Variations in Caspian Sea level and water abstraction from feeder streams will affect the talab level and size. In the 1930s the talab was 4 to 8 m deep (Vladykov, 1964) and the fall in level severely affected the spawning migrations of fishes and the habitat for developing young. The talab is the principal breeding ground for *Rutilus kutum* and it is important for several other species. Freyhof *et al*. (2020) noted that this was one of very few larger coastal wetlands left in the Caucasus area. Further details are given below under the description of the Caspian Sea basin.

Gilan, Anzali Talab, 15 April 1968, Neil B. Armantrout.

vii) Wetlands

Wetlands were originally studied and protected as feeding and overwintering grounds for important waterfowl but they do protect fish populations, which might otherwise be threatened. Access and hunting are forbidden or restricted and often fishing too. Anonymous (1971), Carp (1972) and Dugan (1993) listed and described various wetlands in Iran of international importance, and see Scott (1995) where latitude-longitudes are often slightly different:-

Lower Atrak River and Alagol Lake (37°21'N, 54°35'E)
Farahabad and Larim Sahra (36°45'N, 53°05'E)
Zarrin Kola (36°43'N, 53°00'E)
Bisheh Sar (36°36'N, 52°43'E)
Fereydun Kenar (36°40'N, 52°31'E)
Bandar-e Farahnaz Lagoon (37°25'N, 49°57'E)
Khalij-e Gorgan (= Gorgan Bay) (36°50'N, 53°40'E)
Anzali Mordab (= Talab) (37°25'N, 49°30'E)
Nur Gol (= Nur Lake) (38°00'N, 48°33'E)
Neyriz Lakes (29°30'N, 53°40'E)
Lake Parishan (= Famur) (29°26'N, 51°50'E)
Khuzestan Marshes (30°30'N, 49°30'E)
Dasht-e Arjan (29°35'N, 52°00'E)
Lake Kopibalbalch, Hasanlu Marsh, Yadegarlu Marsh and surrounding marshes (37°00'N, 45°30'E)
Lake Bishovan (37°09'N, 54°52'E)
Amirkelayeh (37°17'N, 50°12'E)
Coastal lagoons north of Gomishan (37°15'N, 54°00'E)

Seyed Mahalleh (36°45'N, 53°00'E)
Sistan lowlands (31°00'N, 61°10'E)

Additional wetlands not of international importance were listed as follows:-

Sefid Rud Reservoir (= Sefid River Dam) (36°45'N, 49°24'E)
Astara (38°25'N, 48°50'E)
Bahr-e Zaribar (35°32'N, 46°07'E)
Soltanabad Marshes (29°30'N, 52°35'E)
Lake Maharlu (29°30'N, 52°50'E)
Dasht-e Mogan (39°30'N, 47°30'E)
Araxes River (= Aras River) (39°10'N, 45°20'E)
Agh Gol (39°55'N, 44°47'E)
Rud-e Shur (35ºº50'N, 50°25'E)
Zarghan and Lapu'i Marshes (29°50'N, 52°50'E)

Hasanzadeh Kiabi *et al*. (2004) listed the top 13 wetlands as Choghakhor (= Chagha Khur), Mond River, Hamun-e Saberi-Hirmand, Khorekhoran, Gandoman, Urmia, Hawr al Azim, Gorgan Bay + Miankaleh + Lapoo, Shadegan, Helleh estuary, Anzali, Arghan of Parishan (= Dasht-e Arjan), and Hamun-e Puzak.

Other wetlands are mentioned in the appropriate drainage basin account. The website http://wetlandsproject.ir/Persian/Default.aspx gave details of the Conservation of Iranian Wetlands Project which is a joint project of the Government of Iran and UNDP/Global Environment Facility to address the root causes of the damage to Iran's wetlands. Lewis and Nazaridoust (2016) discussed development needs and conservation management for Iranian wetlands, with particular reference to Lake Urmia and Sistan, and Pourebrahim (2016) analysed the threats and challenges to the Hawr al Azim wetland. Abedi and Tahami Pour Zarandi (2021) investigated the effectiveness of policies and regulations in protecting wetlands and lakes in Iran and noted the need for reform.

**Environmental Change**

There is evidence for changes in the environment and therefore fish habitats during historical times. Many of these changes are man-made and are on-going. References to change, e.g., habitat loss, pollution, effects of exotic species, etc., can be found in each of the Drainage Basin files below. This topic has been reviewed in general by Coad (1980b) and the references therein, with papers cited under **Climate** above, are relevant. Abdoli (2021) briefly reviewed the threats posed by exotic fishes.

Peritore (1999) gave a general overview of ecological conditions and attitudes to the environment, Foltz (2001) reviewed environmental initiatives, Afasiabi (2003) reviewed the environmental movement in Iran and Valeolahy (2000) reviewed the factors affecting the abundance of fishes and suggested measures for conservation. Jawad (2003b) gave an account of the impact of environmental change on Iraqi fishes which has implications for fishes in neighbouring waters of Iran.

## Drainage Basins

The drainage basins of Iran are shown in the maps below. The delimitation of these basins is somewhat arbitrary. Maps by others have similar boundaries but differ in detail, especially for internal desert basins. Iran is a mountainous country and much of it is desert. There are thousands of small springs and streams with no present or recent connection to other water bodies. Practical considerations required a large scale and I divided the country into 19 major basins based on field work, maps, fish distributions, history of research, works on hydrography and areas deemed important for an understanding of zoogeography and in part after Saadati (1977). Name choices for these basins was somewhat arbitrary and may refer to the basin's major river or to a terminal lake (which can be salt and fishless but has many inflowing rivers and streams). Descriptions of these basins serves to outline the diversity of cyprinoid habitats, the challenges these present for fish, information on other non-cyprinoid species that characterise the basins, introductions of exotics and translocated species, and some zoogeographical relationships. The species content of these basins is summarised under **Biodiversity**.

There are two main types of basin, exorheic where the rivers and lakes drain to the sea and endorheic, where rivers drain to an internal basin such as a lake, or are lost in the desert, and have no connection with the sea. The exorheic basins all fringe the southern part of Iran. The bulk of the basins, in number (15) and area (about 78.1% of Iran), are endorheic. These plateau basins lie at an average altitude of 800 m, alternating with mountains ridges at an average of 2,000 m. The salt lakes and flats of these basins are fed primarily by groundwater rather than rain (Issar, 1967) and water is lost by evaporation. Wolfart (1987) stated that Quaternary environments in the closed or endorheic basins of arid Southwest Asia often have marine and brackish fossils. These are not evidence of marine invasions but of the increasing salinity derived from the mineral content of rainwater. As the water evaporates it leaves behind the minerals and over 10 thousand years or less a saline environment develops.

www.bibliothecapersica.com/articlenavigation/index.html, under drainage, downloaded 24 December 2004, gave four main drainages for Iran as follows:-

| Drainage | Area (sq km) | % |
|---|---|---|
| Caspian Sea | 193,161 | 11.9 |
| Lake Urmia | 54,747 | 3.4 |
| Persian Gulf | 335,864 | 21.9 |
| Interior | 1,626,520 | 61.8 |
| Total | 2,210,292 | 100 |

with the interior drainages as follows (not adding up to the area cited above, however):-

| Drainage | Area (sq km) | % |
|---|---|---|
| Qom (Namak Lake) | 92,332 | 9.0 |
| Damghan | 19,863 | 1.9 |
| Dasht-e Kavir | 200,747 | 19.6 |
| Mashhad (Hari or Tedzhen River) | 43,496 | 4.3 |
| Bejestan Highlands | 91,349 | 8.9 |
| Dasht-e Lut | 166,160 | 16.2 |
| Sistan | 90,813 | 8.9 |
| Jaz Murian | 75,193 | 7.4 |
| Yazd | 105,291 | 10.3 |
| Esfahan | 97,802 | 9.6 |
| Zagros Mountains (Tigris River) | 39,702 | 3.9 |
| Total | 1,022,748 | 100 |

Van der Leeden (1975) summarised water resources of Iran with discharges of principal rivers at various recording stations, listed major dams and reservoirs, and resources and demand. www.bibliothecapersica.com/articlenavigation/index.html, under ab (= water), downloaded 24 December 2004 also listed major dams and gave a general overview of hydrology and has descriptions of various rivers under their names. McLachlan (1988) also considered water resources in Iran. Some of the earlier dam projects were described by Justin and Taleghani (1955). Later dam projects can be located by a search of Iranian newspapers (in English and Farsi). Prior to the Islamic Revolution 13 dams had been built in Iran but the five-year development plan (1990-1995) designed 110 dams of which 22 were under construction in 1993. 60 dams have been constructed after the 1979 revolution (*Islamic Republic News Agency*, 31 August 1998). Akhani (2015) cited 647 dams in Iran with 146 under construction and 537 in the planning stage. Tahbaz (2016) cited, as of 2011, 541 large and small dams had been built, 135 were under construction and 546 were in the planning stage.

*Aquastat* from the Food and Agriculture Organization, Rome (www.fao.org/ag/agl/aglw/aquastat/iran.htm) gave an overview of Iranian water resources and water abstraction and is updated at intervals. The total domestic, industrial and agricultural water abstraction was estimated at 70 cu km in 1993, 51% of the renewable water resources. Annual abstraction from aquifers (57 cu km) was more than the estimated safe yield of 46 cu km. An additional 39 cu km was used annually, 20 cu km for electricity production, 11 cu km for flood

control and 2 cu km for control and thence environmental protection of downstream parts of rivers, the remainder being surplus. The increasing demands will have serious effects on the water supply and hence the fish fauna. Nikravesh (1997) estimated, based on water consumption and population growth, that Iran will be added to the U.N. list of countries facing water shortages in the year 2025.

Kuros (1943) gave accounts of historical water resources and the problems of water supplies in Iran. Lambton (1953, 1969) gave an account of the allocation of water resources in Iran for irrigation. This latter work is important for an understanding of restrictions on fish habitats, e.g., in qanats, dams, rivers and springs. Beaumont (1981) reviewed management of water resources in the Middle East and placed the Iranian resources in a wider context. Anonymous (1961) and Beaumont (1974) outlined water resource development in Iran, the construction of dams, abstraction for irrigation by traditional and modern means, and the demands of industry and domestic consumers of water. All these affect the habitat of fishes, often in deleterious ways. Noori (1966) described the hydrology of surface water in Iran. Pirnia (1951), Anonymous (1961) and Beaumont (1973b) gave accounts of the river regimes in Iran with discharges and runoffs at various recording stations. Peak discharges occur in March to May because of snowmelt. Very low flows occur in summer because of the lack of precipitation, and because of abstraction for irrigation, and flow is mostly from groundwater sources. Most rivers are really streams for much of the year as minimum flows for principal rivers are 0.16-451 cu m/sec, average about 36 cu m/sec. The Caspian rivers are the only ones which lack a distinctive annual rhythm and show flows closely related to precipitation throughout the year. The areas with the largest runoff values are in the northern and central Zagros Mountains and in the Alborz Mountains while lowest runoff values per unit area are found around the deserts in central Iran. In the Zagros and Alborz, annual runoff values can attain more than 300,000 cu m per sq km. Löffler (1956, 1961) studied the limnology of several of the major basins within Iran. The Ramsar Convention on Wetlands has a report on the Islamic Republic of Iran (No. 37, at www.ramsar.org/ram_rpt_37e.htm, downloaded 4 May 2001).

Pirsaheb *et al*. (2015) reviewed heavy metals in Iranian waters where they are important pollutants and indicators of water quality. Concentrations are often above acceptable limits and must impact fishes. Zolfaghari *et al*. (2018) gave a risk assessment for heavy metals according to international standards for fish in Iranian wetlands, mercury and lead being of particular concern. A general description of Iran, its structure and drainage can be found in Harrison *et al*. (1945), Neumann (1953), Fisher (1968) and Krinsley (1970). Water policy development is summarised in Aminipouri (2002). A description of natural areas in Iran, including a list of National Parks and Protected Rivers, can be found in Zehzad *et al*. (2002). The Protected rivers are the Jajrud (= Jaj) and Karaj in the Namak Lake basin, and the Chalus, Sardab, Lar and Haraz rivers of the Caspian Sea basin.

Mazandaran, Sardab River (CC BY-SA 3.0, Zahiri).

The drainage basins are listed below. The general black and white map differs in some details of extent from the coloured basin maps as minor basins are variously included or not.

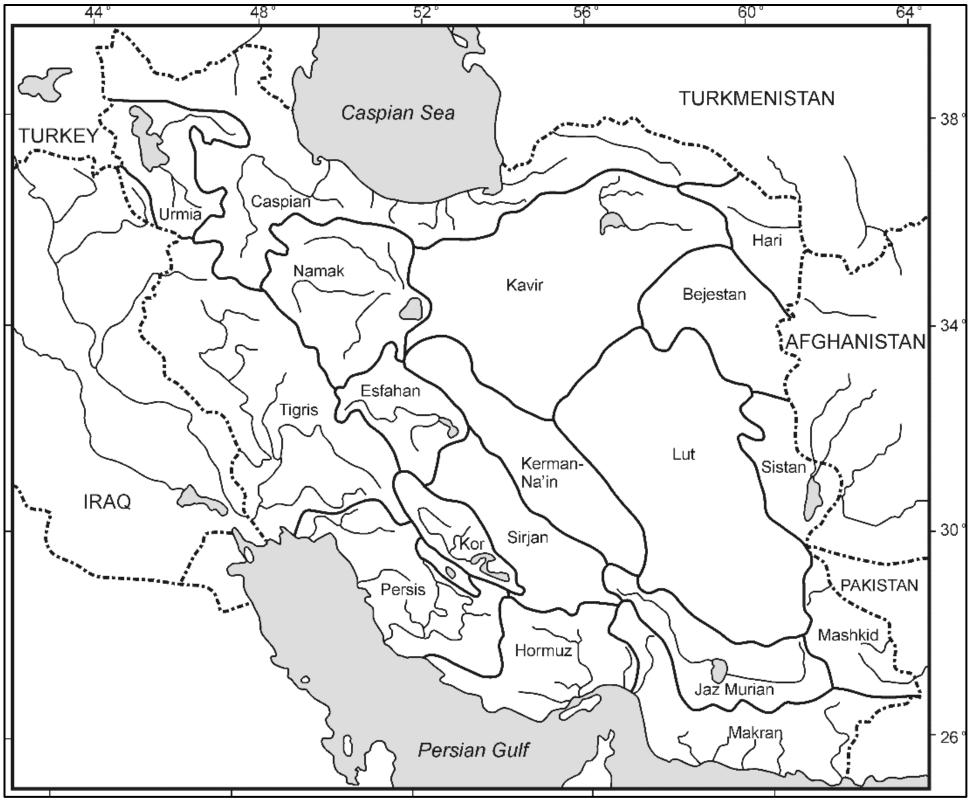
Exorheic Basins:- Hormuz, Makran, Persis (formerly Gulf), Tigris River.

Persian Gulf and Sea of Oman exorheic basins
(IranCatchKhF0, CC BY-SA 4.0, Mahdy Saffar).

Endorheic Basins:- Bejestan, Caspian Sea, Dasht-e Kavir, Dasht-e Lut, Esfahan, Hamun-e Jaz Murian, Hamun-e Mashkid, Hari River, Kerman-Na’in, Kor River, Lake Maharlu, Lake Urmia, Namak Lake, Sirjan, Sistan. The two maps below show these basins except for the northern Lake Urmia, Caspian Sea and Hari River basins.

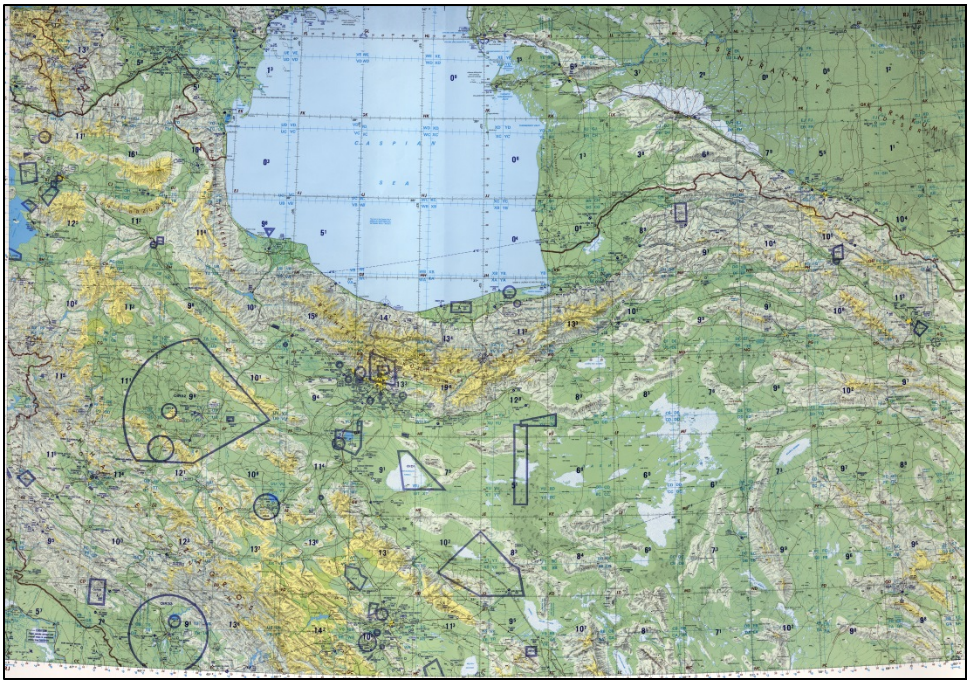
Endorheic central basins
(IranCatchCen0, CC BY-SA 4.0, Mahdy Saffar).

Endorheic eastern basins
(IranCatchEast0, CC BY-SA 4.0, Mahdy Saffar).

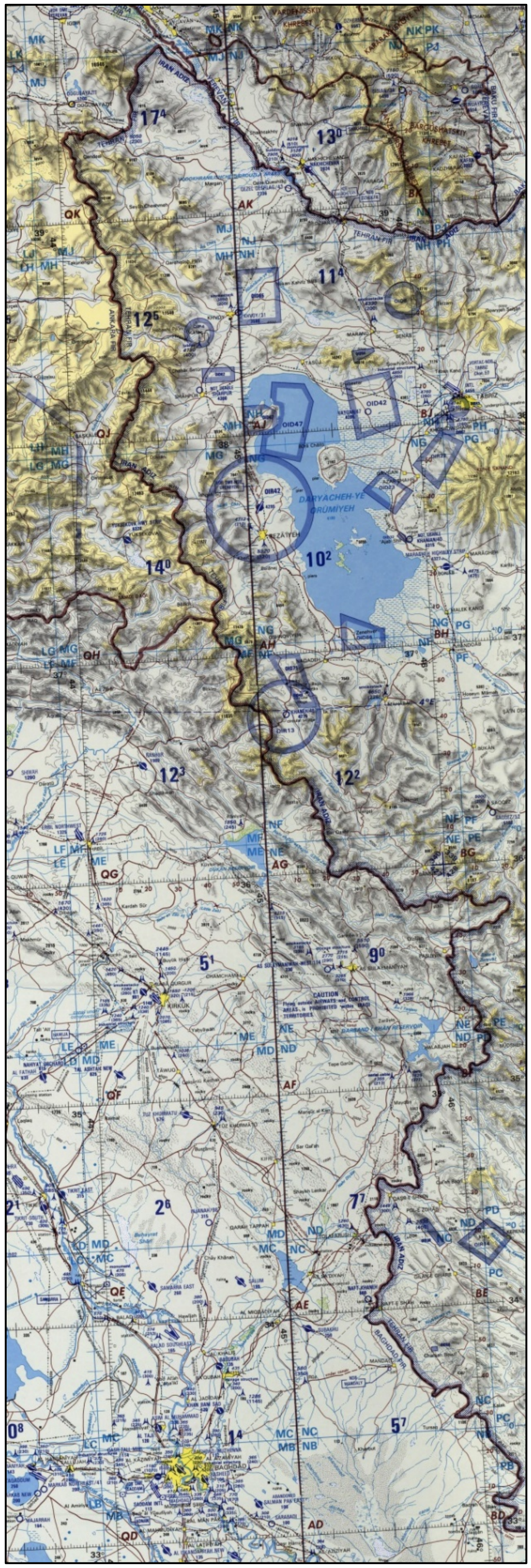



Major drainage basins of Iran
(the Lake Maharlu basin lies between the Kor River and Persis basins),
Susan Laurie-Bourque @ Canadian Museum of Nature.

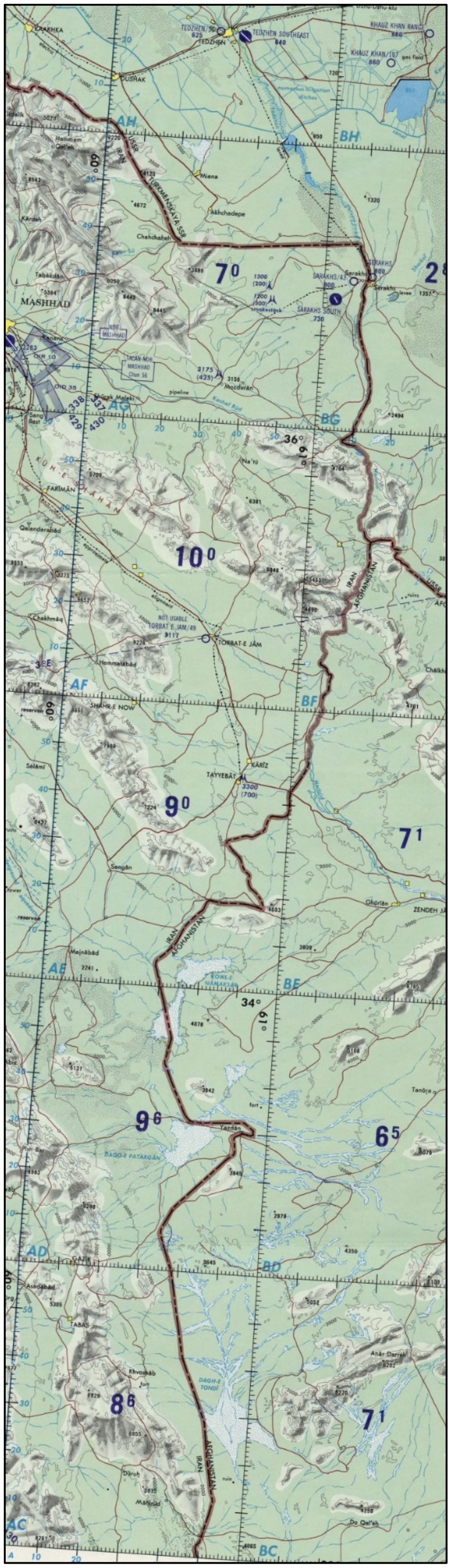
Maps of Iran at various scales are available online from the U.S. National GeoSpatial-Intelligence Agency (www.nga.mil/Pages/Default.aspx) and the University of Texas at Austin Library, Perry-Castañeda Library Map Collection (http://legacy.lib.utexas.edu/maps/iran.html). The Operational Navigation Charts (ONC), Tactical Pilotage Charts (TPC), Joint Operations Graphic (Air) and others were meant for air navigation but nonetheless they give topography, rivers and lakes, and main habitation centres. The U.S. Board on Geographic Names is housed at the U.S. National GeoSpatial-Intelligence Agency too. The original maps can be zoomed in for finer details and a few examples are given below.



Map of Northern and Central Iran, crop from ONC G-5,
U.S. National GeoSpatial-Intelligence Agency.



Map of Western Iran, crop from ONC G-4,
U.S. National GeoSpatial-Intelligence Agency.



Map of Eastern Iran, crop from ONC G-6,
U.S. National GeoSpatial-Intelligence Agency.


Map of Southwest Iran and northern Persian Gulf, crop from ONC H-6,
U.S. National GeoSpatial-Intelligence Agency.

Map of Southeast Iran, crop from ONC H-7,
U.S. National GeoSpatial-Intelligence Agency.

## Exorheic Basins

### Hormuz

The Hormuz (or Hormozgan) basin comprises a number of intermittent streams and rivers which drain to the Straits of Hormuz.

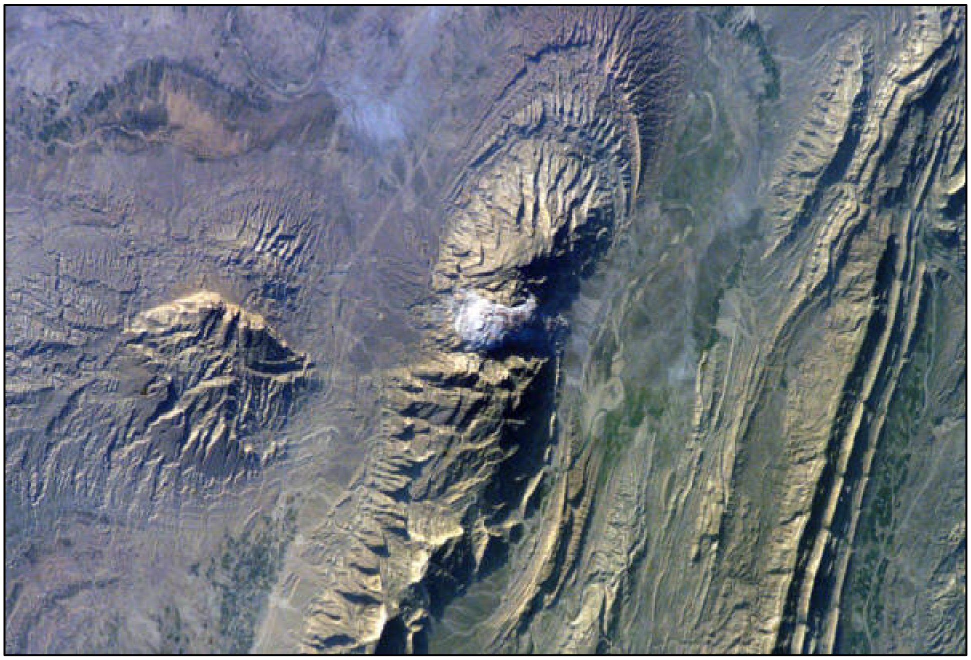
Hormuz basin
(western part)
(IranCatchKhF7, CC BY-SA 4.0, Mahdy Saffar).

None of the rivers has a significant fishery. The basin has a catchment of 55,800 sq km. Rainfall is low and sporadic at this southern end of the Zagros Mountains and streams are not always perennial. Qanats are an important feature and there is a hot spring (41°C) at Genu (27°26'N, 56°20'E) just north of Bandar-e Abbas. Ab anbars are a feature of this dry area and in the adjacent Persis basin, domed and roofed cisterns that collect rain water but these are fishless.

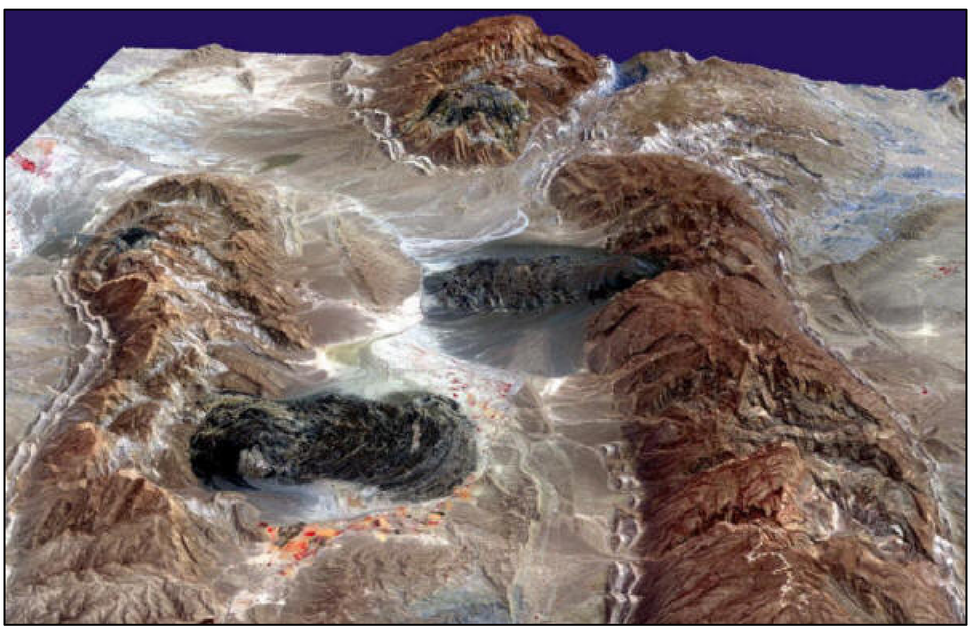
Fars, ab anbar on Khonj-Lar road, 25 November 1976, with Hamid Assadi,
Brian W. Coad.

This area of Iran is rich in salt domes rising to over 1,200 m above the surrounding land surface and consequently surface water is often contaminated and stream banks are rimed with salt (Lehner, 1944; Shearman, 1976; Kent, 1979). Some of the islands off this coast are salt plugs, e.g., Hormuz Island. Temperatures in winter are high in the lower streams, 15-33°C, and must be much higher in summer. These warm and saline streams are home to the endemic cichlids, *Iranocichla hormuzensis* and *I. persa*, and so are distinguished from the fresh waters to the north, east and west. Cichlids were not found in the Minab River in my collections during the 1970s. The Minab River was therefore included in the Makran basin but may well form the easternmost part of this basin. However, the possibility of an introduction of this species to the Minab cannot be ruled out (and see under Makran below). The Minab River is formed from two main tributaries, the Jaghin (32% of the catchment) and the Rudan (67%) rivers and the Minab basin has an area of 10,100 sq km. Barkhordari (2003) gave details of the hydrology of this basin. The Minab or Esteghlal Dam lies 2 km from Minab and opened in 1983 with an initial volume of 334 mcm and a height of 51.5 m.

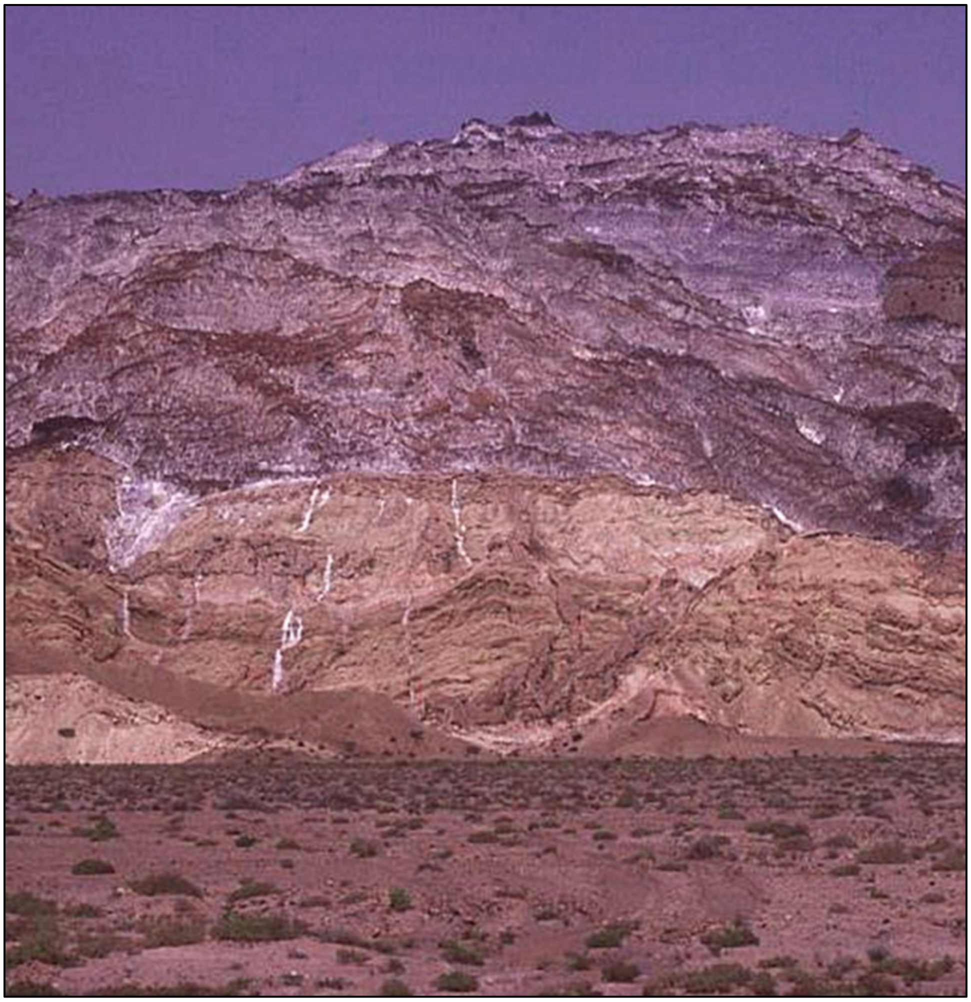
Hormozgan, Hormuz Island
(Iran's Rainbow Island, CC0, NASA Earth Observatory, Lauren Dauphin).



Bushehr, salt dome, Jashak, Zagros Mountains
(CC0, NASA).



Salt domes and salt glaciers, southern Iran
(CC0, NASA).



Hormozgan, salt dome south of Bandar-e Khamir, Brian W. Coad.


Hormozgan, Rudan River, Hamid Reza Esmaeili.

The principal river is the Kul or Kol with its tributary the Shur (= salt) River. The upper reaches of the Shur lie west of Darab (28°45'N, 54°34'E) and mountains here exceed 3,000 m. The upper Shur River basin is the type locality of *Acanthobrama persidis*. The headwaters of the Shur approach those of the eastern tributaries of the Mond River in the Persis basin. The lower valleys parallel the coast and drain eastwards. The Rasul River is a tributary of the Kul, while the Mehran River drains directly into the sea. The Mehran delta lies in the Hara Protected Area (Biosphere Reserve) described by Zehzad *et al*. (1998). The offshore islands such as Qeshm, are poor in fresh water, but have not been thoroughly explored. A number of streams cross the plain east of Bandar-e Abbas (27°11'N, 56°17'E) draining the Kuh-e Furgun at 3,279 m and associated ranges. Although many streams are salty, a freshwater oasis is found at Sar Khun (27°23'N, 56°26'E). Mandegari *et al*. (2014) gave the limnological conditions in waters around Hajiabad.

CMNFI 1979-408, Hormozgan, Mehran River near Bastak, 18 March 1978 (too saline for cyprinoids), Brian W. Coad.

Several islands in the Persian Gulf are included as part of this basin. The largest island is Qeshm but it lacks rivers although there are some small dams to collect rainwater runoff (A. R. Zeanaie, pers. comm., 1999). Species observed are the aphaniid *Aphaniops dispar*, a mudskipper and the introduced *Gambusia holbrooki* (eastern mosquitofish) but apparently no cyprinoids. Water temperatures reach 32°C.

Hormozgan, Qeshm Island and adjacent coast, including the Mehran and Kul rivers
(left and centre)
(CC0, NASA).

Makran

The Makran is the coastal region of southeastern Iran between the Straits of Hormuz and the Pakistan border, possibly derived from mahi khuran (= fish eaters, the ichthyophagi of Classical times). A stream between Sarzeh and Dar Pahn is the type locality of *Barbus baschakirdi* (= *Cyprinion milesi*) and the Tang-e-Sarhe near Siahangari in the Makran is the type locality of *Garra roseae*.

Eastern Hormuz and western Makran basins
(IranCatchKhF8, CC BY-SA 4.0, Mahdy Saffar).

Eastern Makran basin
(IranCatchKhF9, CC BY-SA 4.0, Mahdy Saffar).

Makran, Jaz Murian and Hormuz
(Jaz Murian satellite, CC0, NASA).

Baluchestan, Bahu Kalat River in Iran at left and Dasht River in Pakistan at right,
(Sistan and Baluchistan province - Bahu Kalat river IMG 7909
Pakistan Bolochistan province - Dasht river, CC BY-SA 4.0, sharpened, Bjoertvedt).

Baluchestan, flood in Bahu Kalat River (left) and Dasht River, Pakistan (right)
into Gwadar Bay on 13 January 2020
(Flooding in southern Iran ESA21798304, contains modified Copernicus Sentinel data 2020,
CC BY-SA 3.0 IGO, European Space Agency).

In the west of this region the relief runs in a north-south direction parallel to the coast but from Jask eastwards the relief runs west-east, again paralleling the coast, to the Pakistan border. The rivers and streams of the Makran all drain to the sea at the Straits of Hormuz and the Sea of

Oman. The inland Hamun-e Jaz Murian basin is isolated by mountain ranges reaching peaks in excess of 2,000 m. The coastal drainages are often incised and the larger watercourses pass through tangs over 1,000 m deep (Harrison, 1968).

I have not seen the watercourses between Jask and the upper Geh (= Nikshahr, Kahir, Kaeyr or Kalar) River drainage (mouth is at 25°37'N, 60°08'E) but descriptions by Harrison (1941) indicated they are similar to other areas of Makran. It seems probable that only the Minab and Sarbaz Rivers have, or nearly have, a perennial and continuous flow along most of their course. Even these rivers are quite shallow and the Sarbaz in particular is easily fordable on foot along its entire length (ca. 280 km). The Moradabad River in the Minab River basin is a type locality for *Capoeta anamisensis* along with the Siaho River in the Hormuz basin.

Baluchestan, Sarbaz River at Bondan, 2 December 1977, Brian W. Coad.

The lower Sarbaz River is known as the Bahu Kalat (= Dashtiari or Silup). The Minab River flows over a shorter course (ca. 220 km) than the Sarbaz, but has a greater flow regime. At Minab (27°09'N, 57°05'E) and at Rudan (27°26'N, 57°12'E) the Minab River was up to 100 m wide with an estimated maximum depth in pools of 2-3 m. The lower Sarbaz River was a series of shallow, muddy pools in the bottom of a canyon with some water flowing over sills connecting the pools (in early December 1977).

Habitat of *Cyprinion watsoni*, *Tariqilabeo diplochilus* and the nemacheilid *Paraschistura bampurensis*, CMNFI 1979-0318, Baluchestan, lower Sarbaz River, 2 December 1977, Brian W. Coad.

Rezaii and Zamani Rad (2014) gave water quality parameters for 78 samples from the Minab River, noting severe pollution.

Habitat of *Cyprinion watsoni* and *Garra persica*, CMNFI 1979-0144, Hormozgan, Minab River at Minab, with Brian W. Coad, 27 November 1976, Hamid Assadi.

Hormozgan, Minab River bed and city
(Minab city and Minab river bed in Hormozgan province, southern Iran,
CC BY-SA 4.0, Okruz).

Hormozgan, Minab Dam
(Esteghlal Dam (in Farsi), CC BY-SA 3.0, Majid765)

The lower Sarbaz has been designated a Wetland of International Importance. In its middle and upper course, the Sarbaz varied from a very shallow and narrow stream connecting pools (some of which were fishless, see below) to what must be termed a river in the semi-desert environment of Baluchestan, with a width of 10 m, a depth of about 1 m and fast current. The river is polluted however. Concentrations of lead exceeded established sediment-quality guidelines for adverse effects on aquatic biota at most of the urban/rural sites in a study of the Sarbaz River by Varkouhi (2009). The rock fill embankment Pishin Dam built over the rivers Pishin and Sarbaz is 63 m high, has a crest length of 400 m and can store 175 million cu m of flood waters (http://netiran.com/news/IRNA/html/930418IRGG10.html).

Baluchestan, Sarbaz River near Bondan, 2 December 1977, fishless!, Brian W. Coad.

The other streams of the Makran have little running water, often become isolated pools a kilometre or more apart and regularly dry up along much of their length. Several rivers between the Mazavi (= Geru) River (mouth is at 26°56'N, 56°56'E) and the port of Jask are named and marked prominently on maps, but these were all dry in their lower reaches in late November 1976. Some flow in their upper reaches is to be expected, but its extent will depend on topography and recent climatic conditions. A dam and irrigation network are to be constructed on the Jaghin River east of Jask (*Islamic Republic News Agency*, 26 June 2000).

Coad (1997b) combined the basins of the Makran, Dasht-e Lut, Hamun-e Jaz Murian, Hamun-e Mashkid or Mashkel and the Pakistani Pishin Lora as a single entity, expanding on earlier work by Mirza (1980). Mirza proposed the name Gedrosia for the Baluchistan Plateau west of the Central Brahui and Hala Ranges in Pakistan. The easternmost river along the Makran coast is the Hingol in Pakistan. East of this river the fauna becomes much more diverse at all taxonomic levels and the fauna is an Indus River one. In the north, the Pishin Lora River basin lies partly in Pakistan and partly in Afghanistan. Beyond this basin to the north and northwest lie the Registan Desert and then the Sistan basin, with its distinctive faunal mix including schizothoracines (*Schizothorax*, *Schizocypris* and *Schizopygopsis*) and a crested loach (*Paracobitis rhadinaea*). To the northeast lies an area designated as Yaghistan by Mirza (1980), with its unique faunal association. The westernmost river is the Dasht, whose upper reaches cross the Iranian border. The western limit of Gedrosia is the Mashkel River basin which has several tributaries from Iran. Coad (1997b) proposed that the limits of Gedrosia be extended westwards to encompass the Iranian part of the Mashkel basin, along coastal Makran as far west as the Minab River, and internally to include the Hamun-e Jaz Murian and southern Dasht-e Lut basins. West of the Minab River, the fauna was deemed to be unique in having an endemic cichlid, *Iranocichla hormuzensis* (and now a second species *I. persa*) and in having members of such Euro-Mediterranean and Southwest Asian (= Middle East) cyprinoid genera as *Barbus sensu lato*, *Chalcalburnus* (= *Alburnus*), *Leuciscus* (= *Squalius*) and the cobitid genus *Cobitis* not found further east. However, cichlid specimens have been collected from the Minab River by H.

R. Esmaeili (examined by me in 1997) and this river may properly belong to the Hormuz basin. I did not collect this species in the 1970s and it is possible that the record is an introduction since that time from adjacent rivers as there have been many accidental movements of fishes in Iran associated with fish farming.

Generally, basins within Gedrosia appear most closely related to their geographical neighbours and support the argument for containing these endorheic basins in one division. No basins are strongly and uniquely linked although Makran and Hamun-e Jaz Murian uniquely share *Garra persica* and *Channa gachua*, and Mashkel and Makran uniquely share *Aspidoparia* (= *Cabdio*) *morar* and *Paraschistura baluchiorum*.

At the species level Gedrosia is most closely related to the adjacent Yaghistan and Indus basins to the east, then to the adjacent Sistan and Hormuz basins, and least of all to the remoter Tigris-Euphrates basin. Its principal relationships are eastern, to some extent northern and very little to the west.

The generic pattern is different from the species one. The Sistan basin has the highest share of genera, followed by Yaghistan and Hormuz. The Indus and Tigris-Euphrates share far fewer genera but they have a greater diversity (5.8 and 2.3 times that of Gedrosia). It is therefore not surprising that Gedrosia shares proportionately more genera with immediately neighbouring basins whose fauna at the generic level is also limited. However, omitting genera found in all basins or unique to a single basin, reveals that Yaghistan and Indus share five of seven such genera exclusively with Gedrosia. Only *Capoeta* showed a different pattern being found in the western basins but not Yaghistan and Indus. The last genus is *Crossocheilus* (now *Tariqilabeo*) which is found in the Indus, Yaghistan and Sistan basins. Therefore, generic level comparisons also showed that Gedrosia is most closely related to the east.

The transitional nature of Gedrosia is evidenced by it having the distributional limits of certain wide-ranging species. This is most notable for species reaching their westernmost limits, namely *Aspidoparia* (= *Cabdio*) *morar*, *Crossocheilus* (= *Tariqilabeo*) *diplochilus*, *Channa gachua*, *Bangana dero*, *Puntius sophore*, and *Tor putitora* (the last two not recorded from Iran). Species are probably limited by environmental conditions such as temperature in comparison with the warm waters of South Asia. However, a significant factor, as recognised by local people, must be the poor physical condition of Baluchistan. Freshwater marshes, lakes and large rivers are all absent. Desiccation of water bodies is common and many streams are intermittent. Habitat diversity for fishes is severely limited. All the common fish species are non-predatory - most fishes feed on small insects or scrape aufwuchs from the rocky stream beds.

In contrast to western limits, only one species has a distribution which is principally Southwest Asian and reaches its eastern limit in Gedrosia, namely *Capoeta damascina* (*sic*, presumably *C. saadii*). The remaining species have distributions which are centred on Gedrosia and immediately adjacent basins. There is also a link northward in that some species have an extensive north-south distribution, namely *Garra rossica* and the nemacheilids *Paraschistura kessleri* and *P. sargadensis*.

One of the most interesting features of Gedrosia is its paucity of fishes. Diversity is low, presumably a result of the physical conditions noted above, compounded by desiccation and during climatic variations both past and present. Gedrosia is presumably an important former route of dispersal for taxa from South and Southeast Asia to Southwest Asia and beyond. The significant absences are of taxa found in the Tigris-Euphrates basin to the west and in the Indus basin to the east.

At the family level, five families are found both west and east, but not in, Gedrosia.

These are Cobitidae, Bagridae, Siluridae, Sisoridae and Mastacembelidae. No cobitid or silurid genera are shared. They may be quite ancient and their absence from Gedrosia is by a vicariant event or their dispersal was via a northern route to the Tigris-Euphrates and separately to the Indus. The most significant absences are of such genera as *Mystus* in the Bagridae, *Glyptothorax* in the Sisoridae, *Mastacembelus* in the Mastacembelidae (*Mastacembelus* is not found in eastern Iran and hence does not have a continuous range throughout the Orient (*pace* Travers (1984)), and also *Barilius* in the Cyprinoidei. The last three genera are found in drainages entering the upper Persian Gulf separate from the Tigris-Euphrates basin but probably had a recent connection with that basin during the Pleistocene lowering of sea levels when the Gulf was drained.

Berg (1940) suggested that fish dispersal across this region was facilitated by the coastal rivers of Iranian and Pakistani Baluchestan being part of a single river system in the Pliocene, since submerged by subsidence. This distribution of these genera is not, therefore, a remnant of the dispersal across Iran from Asia. It is possible that the Pleistocene fore-deep of the Himalayas had connections with the Tigris-Euphrates basin which extending down the Persian Gulf as a river valley. Hora (1937) and Menon (1957) referred to wet, marshy, tropical conditions and headwater captures along the whole southern face of the Himalayas and westwards during the Pliocene and early Pleistocene facilitating the spread of fishes from the east to what is now Southwest Asia (= Middle East) and Africa. However, it is here considered unlikely that the Tigris-Euphrates and Gedrosian rivers were once tributary to the Indus when sea levels were lower during glaciations as the Gulf of Oman descends to an abyssal plain at 3,340 m. These taxa probably reached the Tigris-Euphrates basin across the Iranian land mass and subsequently became extinct as desiccation increased. Their absence from Gedrosia is probably by loss.

Hora (1937) and Briggs (1987) considered that cyprinoids entered Africa from Southeast Asia 18-16 MYA, in the early Miocene, while other groups moved through Iran and the Arabian Peninsula beginning in the early Eocene. Kosswig (1951, 1952, 1955a, 1955b) noted the similarity at the generic level between Indian and African fishes, e.g., the cyprinoids *Barilius*, *Garra* and *Labeo*, indicating that these fishes arrived in Africa from India after the desiccation of the Syrian-Iranian Sea in the Pliocene. The primary route, according to Kosswig and to Por (1987), was a northern one around the barrier of the Persian Gulf and Sea of Oman via northern Arabia, Syria and the Levant. Cooling conditions in these areas, and presumably too in Gedrosia, during the Pliocene and especially the Pleistocene glaciations, and arid climates at times, were unsuitable for tropical forms.

Potential endemic taxa are *Cyprinion milesi*, *Bangana gedrosicus*, *Crossocheilus* (= *Tariqilabeo*) *macmahoni*, *Paraschistura baluchiorum*, *Paraschistura bampurensis* (in Iran), and *Triplophysa brahui* (in Pakistan). The systematic position, as species, of *Cyprinion milesi* and *Bangana gedrosicus* need further study, and the distributions of the three nemacheilid species are in contention. Endemism may be relatively high or low dependent on the resolution of these problems.

Fishes in the easternmost part of the basin have a unique predator to contend with among Iranian species. The gandoo (marsh crocodile or mugger, *Crocodylus palustris*) is found in the Sarbaz, Kaju and Bahu Kalat rivers including the Pishin Dam, makeshift lagoons and fish culture ponds. It feeds on *Cyprinus carpio* and the mudskipper *Periophthalmus* (Crocodile Specialist Group Newsletter, IUCN, 18(1), WWW Edition, downloaded 16 December 1999 from www.flmnh.ufl.edu/natsci/herpetology/newsletter/news181b.htm; report by A. Mobaraki; A. Mobaraki, pers. comm., 2000). The *Cyprinus carpio* are escapees from fish farms. Asghar

Mobaraki (pers. comm., 8 January 2012) recorded a fish kill on 26 December 2011 at the Zirdan Dam construction site on the Kaju River. Species included *Tariqilabeo diplochilus* and the goby *Glossogobius giuris* along with Mugilidae.

Baluchestan, gandoo or marsh crocodile, Environmental Research Center of Rikookesh, (Gandoo – Baluchistan – Iran, CC BY-SA 4.0, Amin Noubahar).

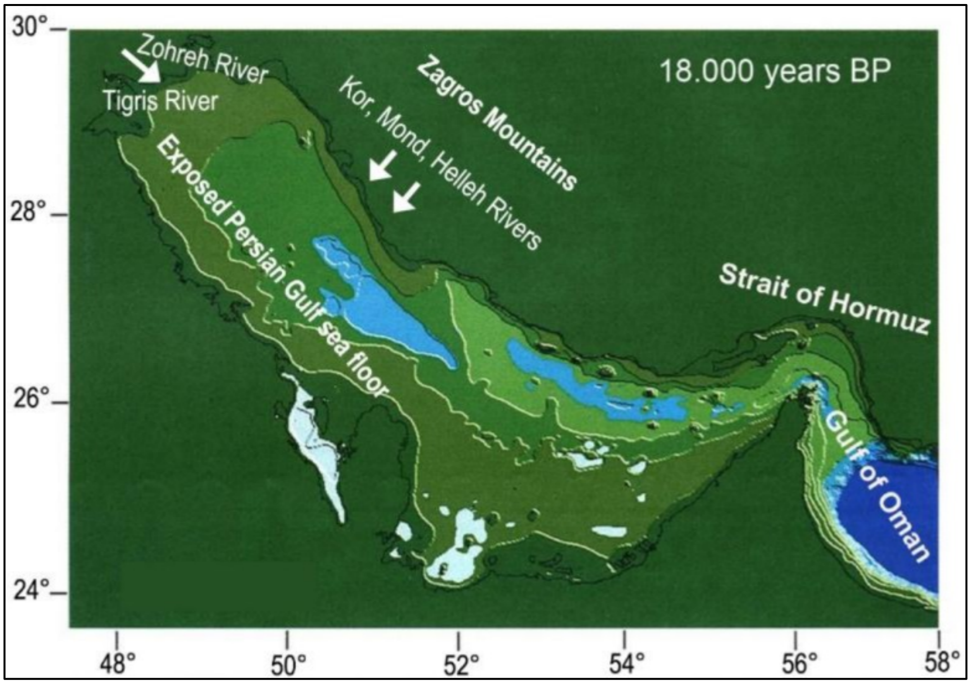
Persis

This basin comprises rivers which drain the southern Zagros Mountains to the head of the Persian Gulf, but which are not now tributaries of the Tigris River nor are they the salt streams of Hormuz.

Persis basin
(northern part)
(IranCatchKhF5, CC BY-SA 4.0, Mahdy Saffar).

Persis basin
(southern part including Mond River basin)
(IranCatchKhF6, CC BY-SA 4.0, Mahdy Saffar).

None of these rivers has a significant fishery. Esmaeili *et al*. (2015) named this basin Persis and reviewed the diversity and origins of the fish fauna. It was formerly called the Gulf basin. In the Pleistocene, the Palaeo-Kor River drained from the High Zagros into the Persian Gulf (Esmaeili *et al*., 2014) connecting the Kor basin to the Persis basin. The present-day biogeography of freshwater species indicates that the Persis, Tigris River and Kor River basin systems must have been connected to each other in the recent past. A plausible scenario suggests that the three drainage systems formed a single network during the Last Glacial Maximum of the Late Pleistocene (21,000-18,000 BP). At that time, the floor of the Persian Gulf was exposed due to the global fall in sea level, and the Tigris and Euphrates (Tigris Basin), the Mond and Helleh (Persis basin), Kul (Hormuz basin) and also the Kor River (ancient exorheic Kor basin) extended onto what is now the floor of the Persian Gulf, where they came together (Lambeck, 1996; Teimori *et al*., 2012).




Exposed sea floor of the Persian Gulf Sea during the Last Glacial Maximum of the Late Pleistocene at 18,000 years BP, with possible freshwater areas in depressions (marked in blue); elevations above sea level are indicated with different green colours at 20, 50, 100 and 150 m; arrows indicate river runoff from the Zagros Mountains, after Esmaeili *et al*. (2015).

This postulated interconnection, which lasted until the Holocene sea-level rise at around 12,000 BP, offers a persuasive explanation for the similarities observed between the fish faunas in drainage systems that are now wholly isolated from each other (Esmaeili *et al*., 2014). It may explain the close relationship of *C*. *mandica* found in the Persis basin (Mond and Helleh River drainages) to *C*. *trutta* found in the Tigris River drainage. Alwan *et al*. (2016b) considered the same explanation for the *C*. *damascina* species complex distribution patterns. These results are also confirmed by linkage between the origination time of *C*. *mandica* and the time of the above events (Ghanavi *et al*., 2016). Geiger *et al*. (2014) also considered dispersal and vicariance events as an important cause of speciation in the Mediterranean hot spot (Zareian *et al*., 2018). The presence of *Chondrostoma orientale* in the Kor River basin but not the Persis basin is probably due to headwater capture from the Tigris River basin of a common ancestor with *C*. *regium*.

Esmaeili *et al*. (2015) predicted geographic distributions of eight species (including *Arabibarbus grypus*, *Carasobarbus luteus*, *Capoeta saadii* and *Luciobarbus barbulus*) from this basin based on bioclimatic variables and using Species Distribution Modelling. A relatively large area of suitable climate for these native Persis species extended to western parts of Iran. The most important variables were minimum temperature of coldest month (*C*. *luteus*), isothermality (*A*. *grypus*), precipitation seasonality (*C*. *saadii*) and precipitation of wettest quarter (*L*. *barbulus*).

At its northern edge, the Zohreh River flows across the Khuzestan plains and is close to Tigris River tributaries. The Tang-e Shiv River in the Zohreh River drainage is the type locality of *Capoeta ferdowsii*. Esmaeili *et al*. (2015, 2017) did not include the Zohreh River in the Persis

basin but it drains to the Persian Gulf directly and is included here for convenience. Other major rivers are the Helleh, which debouches into the Persian Gulf north of Bushehr (28°59'N, 50°50'E) and the Mond (= the classical Sitakos and formerly called Mand) (Ross, 1883), which, with its tributaries, drains much of Fars Province to the Persian Gulf south of Bushehr. The Mand or Mond and its basin is the type locality of *Alburnus caudimacula* (= *A. sellal*), *Capoeta capoeta intermedia* (= *C. mandica*), *Capoeta barroisi mandica* (= *C. mandica*), *Cyprinion tenuiradius*, *Discognathus crenulatus* (= *Garra rufa*), *Garra mondica*, *Barbus barbulus* (= *Luciobarbus barbulus*) and *Systomus albus* var. *alpina* (= *Carasobarbus luteus*). Near Shiraz, the upper Mond is known as the Qarah Aqaj or Kavar River (= the classical Zakan). The Band-e Bahman, a weir or small dam on this river near Kavar, was constructed at an estimated 2,000 years ago and diverted water for agriculture (Morshedi and Daneshvar, 2007).

Fars, Qarah Aqaj, 2 km above Band-e Bahman, 14 July 1967, Neil B. Armantrout.


Fars, Band-e Bahman Dam on Qarah Aqaj, 14 July 1967, Neil B. Armantrout.

Mirzaei et al. (2017) took water samples from 11 stations along six rivers in this basin, namely the Baghan, Bahoosh, Dalaki, Helleh, Mond and Shapur, during 2011-2013. The Baghan and Dalaki rivers were categorized as bad quality while the Bahoosh, Helleh, Mond and Shapur were in the average quality category. The rivers were suitable for agricultural purposes while they should be purified for drinking purposes. Shahradnia *et al*. (2020) examined water quality at 10 stations over 190 km in the Qarah Aqaj (*sic*, included Mond River) using macrobenthos as a bioindicator. Water from midstream to the Persian Gulf had severe pollution as there was extensive farmland with runoff pesticides and herbicides and the effluent from sand mines.

The Mond River is 480 km long and occupies a basin of about 60,000 sq km. Its flow is reduced by a low snow cover (although there can be torrential spring flow), water seepage, evaporation and abstraction for irrigation purposes. Discharge has been estimated to range from 10-2,025 cu m (Merchant and Ronaghy, 1976). It was also polluted near Kavar (29°11'N, 52°44'E) by sewage and agriculture residues and does dry up to a series of isolated pools there.

Habitat of *Alburnus sellal*, *Capoeta trutta* and *Cyprinion macrostomus*,
CMNFI 1979-0020, Fars, polluted Qarah Aqaj outside Kavar with Sassanian bridge,
26 January 1976, Brian W. Coad.

Bushehr, lower Mond River
(Mond River, CC BY-SA 3.0, Hadi Karimi).

Bushehr, Mond River at Konari
(Konari, Iran - 123889002, CC BY 2.0, RemusShepherd)

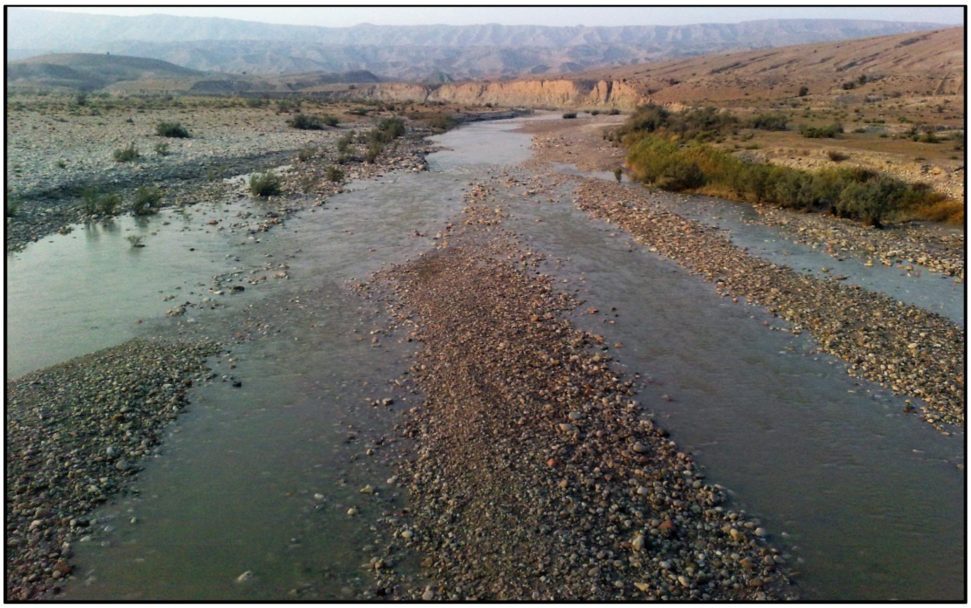
A fish kill, numbering in the many thousands, occurred in the Mond near Shiraz in 1977 and was attributed to chemicals used in spraying against malarial mosquitos. The people hired to spray village houses either dumped quantities of the chemical into the river to reduce their work load or washed out containers in the river (Coad, 1980b). Temperature range is at least 20C° between winter and summer, with a high of 35.4°C, and water quality is poor to medium from agricultural activities (Moghdani *et al*., 2013). The middle part of the Mond basin was examined for groundwater degradation and 13.4% was under severe hazard and 70.8% under moderate hazard (Masoudi *et al*., 2009). Degraded groundwater resources affected springs and rivers in the basin. Drought on the Jahrom plain, one of the Mond sub-basins, showed a groundwater level drop of 14.7 m in 12 years and salinity of plain water rose from 650 to 1,100 mmohs/cm (Jabbari *et al*., 2015). The delta of the Mond is a Protected Area of 46,700 ha. There are thin oxbow lakes and associated marshes.


Fars, upper Mond River basin near Jahrom, 26 November 1974, Neil B. Armantrout.


Bushehr, lower Mond River at Searaf Highway (Mond River …., CC BY 3.0, (H-Karimi).

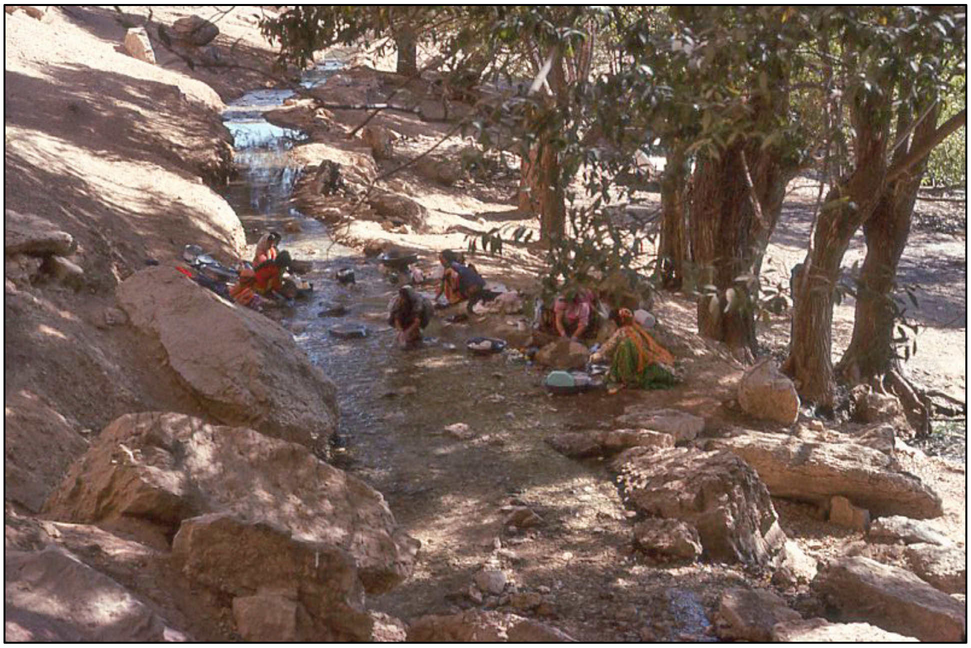
The Mond has a number of tributaries, at least two of which are called Shur (= salt) River. Conductivity near Firuzabad on the Shur River was 695-715 µM/cm but rose to 20,000 µM/cm below salt domes further downriver. Zamanpoore (2017) examined the saline Dehram River in the Mond River basin for aquaculture. Salinity, electrical conductivity and total dissolved solids increased from station one to three, varying from 6.6 g/l, 14.3 g/l and 12,800 µs/cm to 13.5 g/l, 17.7 g/l and 16,500 µs/cm. Dissolved oxygen and oxygen saturation were

higher in station three, and in autumn and winter. Nitrite showed the lowest value in winter (0.006 mg/l) and the highest value in spring (0.013 mg/l). Nitrate showed the lowest concentration in station three (0.43 mg/l), but no differences were seen among seasons. Ammonium showed no differences among stations or seasons. Phosphate levels in station one and three were 0.13 mg/l to 0.17 mg/l, with the highest level (0.29 mg/l) seen in the spring. Five species of fishes were identified in the river, which all were widely favored by local people. These cyprinoids were *Alburnoides bipunctatus* (*sic*, but no *Alburnoides* are recorded from this basin), *Capoeta barroisi* (= *C. mandica*), *Cyprinion tenuiradius, Garra persica* (possibly *G. rufa*) and *Luciobarbus barbulus*. Some of these have been categorized as edible in previous studies, others as ornamental. Intensive growth of an algal species throughout the river demonstrated a potential for algal cultivation. The significant role of algae in production of food for both man and livestock is well recognized in the aquaculture industry.



Fars, Shur River near Koordeh, Mond River basin
(Shoor River, Koordeh - panoramio, CC BY 3.0, cropped, H-Karimi).

The more southerly headwaters are close to those of the Shur River of the Hormuz basin between Darab (28°45'N, 54°34'E) and Fasa (28°56'N, 53°42'E). The headwaters of the Mond lie north-west of Shiraz near Kuh-e Tabask at 2,318 m (29°52'N, 51°49'E) and there are a series of springs in this area called Chehel Cheshmeh (= Forty Springs; not exactly 40 springs, 40 being a number used to denote many as in Ali Baba and the Forty Thieves from *One Thousand and One Nights*) which feed the Mond. Nearby is the Dasht-e Arjan (29°39'N, 51°58'E), a small enclosed basin with a flooded plain encompassing about 24 sq km at maximum. It is fed by small springs and streams. The water is fresh since swallow holes in the southeast corner of the plain drain water away with a salt flushing effect. Shiraz was once "chiefly supplied with fish from this lake" (Ouseley, 1819-1823) but it does not now support such a copious ichthyofauna. A report from *Reuters* (8 June 2000) cited a fish kill numbering in the hundreds of thousands from the "Arjang lagoon, in a suburb of the southern city of Shiraz", presumably this lake, after it dried up (www.iran-sabz.org/news/fish2.htm).



Fars, Dasht-e Arjan springs, 8 November 1976
(only the mosquitofish *Gambusia holbrooki* caught), Brian W. Coad.

The Haft Barm-e Kudian lie about 20 km north of Dasht-e Arjan at 29°49'N, 52°02'E at 2,200 m. The seven lakes lie in rolling country and the largest is about a 1 sq km. Some may dry up in certain years but fish were found suggesting that there is a perennial water supply (Cornwallis, 1968a). Scott (1995) said the southern five lakes generally dried out completely in summer. In winter the lakes froze over. They are about 2-3 m deep and some are slightly saline. These lakes have been stocked with *Esox lucius* (northern pike), *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella* and *Gambusia holbrooki* (eastern mosquitofish).

Surber (1969) gave some spot data on pH, total alkalinity, calcium-magnesium hardness, chlorides and free $CO_2$ in the Mond basin. Near Firuzabad, the concentration of total dissolved solids was 333 mg/l while near Jahrom it reached 6,937 mg/l, indicating how there can be great variations in habitat within the same river basin over short distances, depending on local geology.

The Zohreh River and its tributary the Shul, are over 400 km long and have their headwaters near Kuh-e Barm Firuz at 3,673 m (30°25'N, 51°58'E) whose northern flank spawns the Khersan River, a Karun tributary in the Tigris basin. Its basin is estimated to be 15,500 sq km. The Fahlian River is a tributary of the Zohreh with a catchment of 2,775 sq km (see habitat photograph under *Carasobarbus sublimus*). Gorjipoor *et al*. (2007) carried out a limnological investigation of the Zohreh River. Manshouri *et al*. (2011) sampled 15 stations along the Zohreh River for dissolved oxygen, pH and nitrate and found levels were acceptable at all stations, except for pH in some according to World Health Organization standards but acceptable with others. The Kowsar or Kosar Dam on the Kheyrabad River, a Zohreh River tributary, is 337.5 m high, its crest is 126 m and the reservoir capacity is 450 million cu m. Jabbari and Boustani (2011) assessed the water quality in the reservoir and found a dissolved oxygen range of 6.99-8.78 mg/l and a biological oxygen demand range of 2.3-25.9 mg/l, both in an appropriate range. Boustani *et al*. (2011) examined water and groundwater from the dam watershed for nickel and found samples were within acceptable limits although there was room for improvement.

Fars, near Ardakan, fishless snowmelt stream in the upper Zohreh River basin with freezing Sylvie Coad, April 1976, Brian W. Coad.

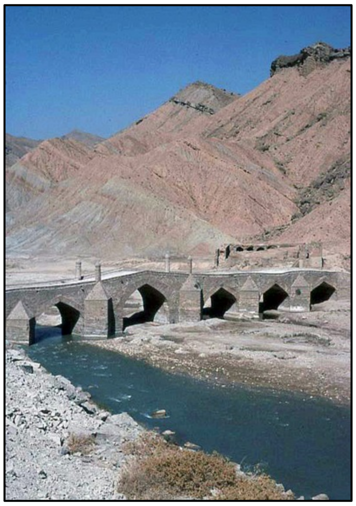
The Helleh River receives the Dalaki (205 km) and Shapur (231 km) rivers which drain the lower Zagros ranges west of Shiraz. Its basin is estimated to be 20,300 sq km (Shiati (1989) gave 10,000 sq km) and includes Lake Parishan or Famur. Shiati (1989) gave an account of salinity in the rivers of this basin. Saline springs and salt domes increase the salinity about 10 times as the rivers flow down from the mountains. Total dissolved solids in the upper reaches of this basin are 366 mg/l, rising to 4,219 mg/l in the lower reaches. Geological sources of sulphur also add to the chemical makeup of these waters. There are no important sources of industrial pollution along these rivers but humans, domestic animals and agriculture are the main pollution sources. The levels of pollution are in the acceptable range (Gh. Izadpanahi, pers. comm., 1995) as are insecticide levels (Shayeghi *et al*., 2007). Ramezani and Hashemi (2014) analysed water quality in the Helleh River at various stations and those with the worst quality were under the influence of evaporitic formations, salt domes, salt springs and agricultural activities.

Aquaculture in the area (Helleh and Mond river basins) has not had obvious effects on coastal water quality (Omidi, 2006). The delta of the Helleh River is a complex of brackish and fresh marshes and lagoons with a maximum depth of 3.5 m. It is the largest freshwater marsh system on the Persian Gulf coast in southern Iran. It is designated as a Protected Area (42,600 ha). This area developed in the early 1970s when the main river channel was diverted onto the coastal plain.

Bushehr, Dalaki River near Doroudgah,
(CC BY-SA 4.0, Ehsan Mohtashami).

Bushehr, Dalaki River on Shiraz-Bushehr Road

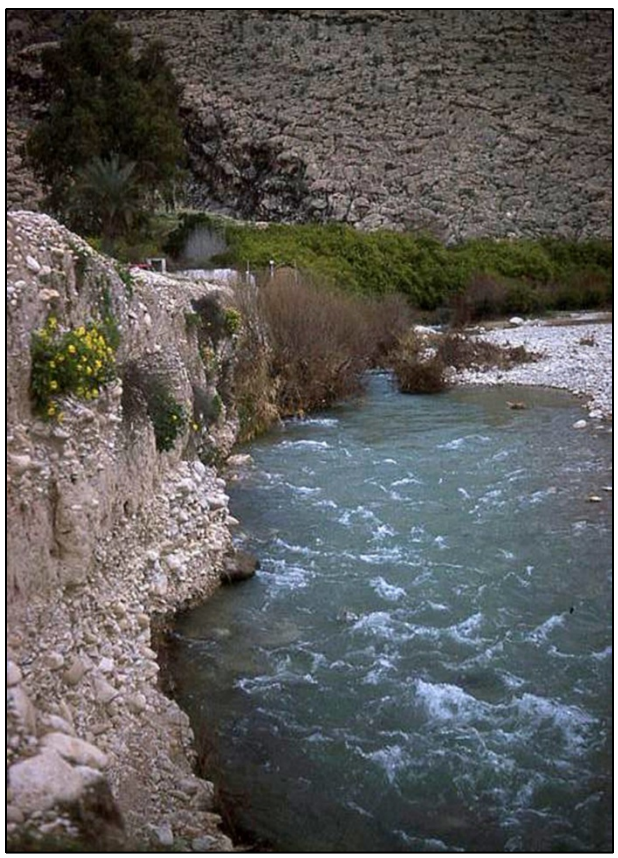
(Dalaki River - Bushehr Road - Dalaki valley ^ river - panoramio, CC BY 3.0,
Alireza Javaheri).




Habitat of *Alburnus sellal*, *Barilius mesopotamicus*, *Cyprinion tenuiradius* and *Garra rufa*,
Bushehr, Moshir Bridge over the Dalaki River near Borazjan at different seasons,
left 20 October 1976, Brian W. Coad and right 30 April 2012,
(Moshir Bridge on Dalaki river Borazjan Iran, CC BY 3.0, Alireza Javaheri).

Fars, Shapur River Valley, January 1976, Brian W. Coad.


Fars, Shapur River Valley, January 1976, Brian W. Coad.


Fars, Shapur River at Bishapur, January 1976,
Brian W. Coad.

Fars, Shapur River near Bishapur, Neil B. Armantrout.

Fars, Shapur River at Bishapur, January 1976, Brian W. Coad.

A cave at Bishapur above the Shapur River was reputed to house a deep lake full of fish but this has not been investigated and may only be a local legend (Mounsey, 1872).

Endorheic Lake Parishan, Perishan or Famur (29°31'N, 51°48'E) is a particular feature of the Persis basin that encompasses 25-52 sq km at about 820 m near Kazerun, is fed by about 80 fresh and brackish springs with a discharge of about 800 litres/second, and supports a fish fauna near the springs. In years of heavy rainfall, the fresh areas expand only to contract in dry years. The wetland has dried in some dry years, e.g., in 2011 and drought was a condition in 2020. There are about 300 illegal wells and 650 permitted ones around the lake (Bakhtiari, 2020a). The catchment basin of the lake is about 270,000 ha. Subsistence fishing occurred here (Hemmati, 2016).

Habitat of *Carasobarbus luteus* and *Garra rufa* (along with the spiny eel *Mastacembelus mastacembelus*, the mugilid *Planiliza abu* and the eastern mosquitofish *Gambusia holbrooki*), CMNFI 1979-0304, Fars, Lake Parishan, with Dr. R. E. Lee, 24 October 1977, Brian W. Coad.

Fars, Lake Parishan, 24 October 1977, Brian W. Coad.

Fars, Lake Parishan
(parishan lake - panoramio, CC BY 3.0, Farid Atar).

An account of the lake was given in Farsi by Maafi (1996a, 1996b, 1996c) and by Hemmati (2016) who also investigated human and climate impacts. The lake is eutrophic and low concentrations of oxygen periodically cause fish mortalities. The reed beds are set on fire to increase the available agricultural land and this process results in a sediment input with the consequent decrease in water depth, fingerling habitat destruction, and fish mortality through

sediments clogging gills. Overfishing is also a problem. Wastewater and sewage enter the lake untreated and this enhances algal growth and eutrophication. Fishery ponds are established west of Lake Parishan resulting in exotic escapees. During periods of low rainfall, Parishan becomes a shallow saline lake and presumably fish habitat is limited to the immediate vicinity of freshwater springs. The springs harbour *Arabibarbus grypus*, *Capoeta saadii*, *Carasobarbus luteus*, *Cyprinion tenuiradius*, *Garra rufa*, the exotic *Gambusia holbrooki* (eastern mosquitofish), the mullet *Planiliza abu* and the spiny eel *Mastacembelus mastacembelus* (and see below). Lotfi (2010) gave a baseline report on the lake including physical, faunal and human factors. Identification of two fish species (*Capoeta fusca* and *C. trutta*) listed by Lotfi (2010) is suspect. The annual harvest of fishes was given as 200-400 tons and presumably includes the stocked species *Ctenopharyngodon idella*, *Cyprinus carpio* and *Hypophthalmichthys molitrix*. Golchin Manshadi *et al*. (2014) listed by frequency *Capoeta barroisi persica* (presumably *Capoeta mandica*), *Chalcalburnus sellal* (= *Alburnus sellal*), *Barbus luteus* (= *Carasobarbus luteus*), *Cyprinus carpio*, *Garra rufa obtusa* (= *Garra rufa*), *Carassius carassius* (probably *C. auratus*), the spiny eel *Mastacembelus mastacembelus*, the mugilid *Liza abu* (= *Planiliza abu*) and *Barbus grypus* (= *Arabibarbus grypus*). Frequencies also varied by season. Lotfi (2018a) also gave a brief overview of the lake. Fish were dried and sent to Shiraz as luxuries in the past (Merritt-Hawkes, 1935).

The ringing marshes are eutrophic and have halophytic plants of the genera *Salsola*, *Kochia*, *Camphorosma* and *Halocnemum* along with extensive reed beds of *Phragmites communis* and *Typha*. This marshy shore attained a water temperature of 31°C in early June when air temperature was 43°C (4 June 1977 at 1330 hours, CMNFI 1979-0240). Maximum depth is about 6 m, falling in summer to 3.87 m and in low water level conditions below 2 m. pH is 7-8 and can exceed 8.5, inhibiting fish growth (Lotfi, 2010). Conductivity is 5 to 6,000 micromhos (Lotfi (2010) gave a range of 0.5-12.0 dS/m). Hydrological conditions vary with locality around the lake, and with water levels and input from springs seasonally and in dry and wet years. Over 900 wells around the lake reduce recharge of the wetland. The drainage basin encompasses about 290 sq km. Urdu and Owfi (2012) carried out an environmental analysis of Lake Parishan and found climate change and drought were major problems, not susceptible to correction.

Golchin Manshadi *et al*. (2014) surveyed the frequency of the larvae of the zoonotic nematode *Contracaecum* sp. in 170 fish caught in hot and cold seasons. The mean infection in *Barbus* (= *Carasobarbus*) *luteus* was 6 and 2 parasites per fish in hot and cold seasons respectively, in *Capoeta barroisi persica* (probably *C. mandica*) was 3.2 and 1.5, in *Garra rufa obtusa* (= *G. rufa*) was 6.833 and 2, in *Chalcalburnus sellal* (= *Alburnus sellal*) was 9.5 and 2, and in *Cyprinion macrostomus tenuiradius* (= *C. tenuiradius*) was 5 and 2.5.

Södergren *et al*. (1978) recorded pollution in fish from this lake and the Shapur and Kupor rivers. Only small amounts of the organochlorine chemical *p,p′*-DDE were found in the lake but the rivers had very high levels of DDT and its metabolites DDE and TDE. At this time DDT was used for indoor spraying against malaria-infected mosquitos and insecticide containers were cleaned in the rivers after spraying. Kafilzadeh *et al*. (2012) found DDE to be the predominant residue in water, sediment and fish samples. DDT, lindane, endosulfan, heptachlor and chlordane were also found in sediment and fish although chlordane and heptachlor were absent in water. [The fish were identified as *Barbus brachycephalus caspius*, and were more likely to be *Carasobarbus luteus*]. Mahmoodi and Javanmardi (2010) found human faecal contamination from villages around the lake. Elmizadeh *et al*. (2017) examined heavy metal

levels (copper, iron, manganese, zinc) in sediments from Lake Parishan but these levels were of the lowest risk and their origin was natural.

Lake Parishan is a type locality for *Systomus albus* var. *alpina* and for *Barbus parieschanica* (both = *Carasobarbus luteus*).

Lake Parishan and the nearby Dasht-e Arjan (29°37'N, 51°59'E) are a Ramsar Site (World Conservation Monitoring Centre, 1990). They lie within the Arjan National Park and International Reserve which encompasses 65,750 ha as established in 1973. However, the Park has been downgraded to a Protected Area of 52,800 ha with the Ramsar Site being the wetlands of Lake Parishan at 4,200 ha and Dasht-e Arjan at 2,400 ha (Khan *et al*., 1992). Both legal and illegal wells surrounding Parishan affect recharge of the lake although steps have been taken to block illegal wells, manage legal ones and prevent new wells (*Iran Daily*, 12 April 2012). Dasht-e Arjan at 1,950 m is a shallow, eutrophic freshwater lake fed by runoff, precipitation and the Salmon springs. The lake area in winter may be 1,950 ha but shrinks in summer to a few hundred hectares. It dried completely in 2001. There is an outflow through swallow-holes in the south-east, traditionally linked to Lake Parishan. The lake margin and the spring-fed marshes have *Phragmites communis*, *Typha* and *Juncus* along with aquatic vegetation. Dasht-e Arjan is cooler than the environs of Lake Parishan because of its higher altitude - 15-35°C in summer and -10-15°C in winter as opposed to 22-40°C and 5-15°C. The Arjan and Parishan wetlands have the exotics *Carassius auratus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *H. nobilis* and *Pseudorasbora parva* (Gholamifard *et al*., 2015).

As well as the rivers described above, springs and qanats are important in the Persis basin. The Dalaki mineral springs have a temperature range of 30-38°C and a discharge of 200 l/s. They are at 130 m above sea level and their hydrology, geology and chemistry was reviewed in Kompani-Zare and Moore (2001).

The Shabankareh Dam is a diversion dam in the lower Helleh River basin and several other dams have been planned for this basin. Small canals or diversions are also present in this basin (Borowicka, 1958).

Berg (1940) placed this basin, the Hormuz basin and the Makran basin as part of the Sind Province of the Indian Subregion of the Sino-Indian Region. Its eastwards extent is the lower and middle Indus River. The Iranian portion is called the Southern Iranian District. Small southern Iranian rivers belonged to a single river basin in the Pliocene, facilitating dispersal according to Berg.

## Tigris River

The Tigris-Euphrates basin is the largest and most important river system between the Nile and the Indus. Details of its biology can be found in Rzóska (1980) but comparatively little was based historically on the Iranian part of this basin although Nümann (1966) gave some limited data on chemical and physical parameters. There are now an increasing number of studies on environmental conditions in Iran. Studies on limnology and pollution were formerly restricted mostly to waters of Iraq, but probably applied equally well to Iran, certainly as far as those marshes which cross the border are concerned and for the Shatt al Arab, part of which forms the southern border of Iran and Iraq. Such studies include Cressey (1958a), Jacobsen and Adams (1958), Mohammed (1965, 1966), Al-Hamed (1966c), Salonen (1970), Al-Saadi and Arndt (1973), Al-Saadi *et al*. (1975), Al-Sahaf (1975), Arndt and Al-Saadi (1975), Kell and Saad (1975), Saad and Kell (1975), Al-Hamed (1976), Saad (1978a, 1978b), Saad and Antoine (1978a, 1978b, 1978c, 1982, 1983), Maulood *et al*. (1979, 1981, 1993), Sarker *et al*. (1980), Al-

Daham *et al*. (1981), Huq *et al*. (1981), Antoine and Al-Saadi (1982), Schiewer *et al*. (1982), Antoine (1983), DouAbul *et al*. (1987, 1987, 1988), Abaychi and Al-Saad (1988), Abaychi *et al*. (1988), Mohamed and Barak (1988), Al-Saadi *et al*. (1989), Hussain *et al*. (1991), Kassim and Al-Saadi (1995), Partow (2001), Richardson (2018), Jawad (2021), among others. Ionides (1937) described the river regimes of the Tigris-Euphrates basin, MacFadyen (1938) the water supplies, El Kholy (1952) the hydrology of the Tigris River, Buringh (1957) the physiographic regions, shores and irrigation systems on the lower Mesopotamian plain, and Al-Khashab (1958) the water budget of the Tigris-Euphrates basin, mainly referring to waters in Iraq. Scott (1995) gave details of wetlands in Iraq, some of which border and/or are contiguous with Iranian wetlands, and whose general ecological features are very similar. Shapland (1997) reviewed water disputes in the Middle East although western Iranian rivers flow out of the country and are not likely to be affected apart from any losses in shared habitats or refuges in border areas. However, Voss *et al*. (2013) documented groundwater depletion in western Iran which will have serious effects on springs and rivers. Jafarzadeh *et al*. (2004) identified industrial sources of water pollution for the Dez, Jarrahi, Karkheh, Karun and Zohreh rivers in Khuzestan Province. The Karun has 1,044 active industrial plants, for example, and has a heavy metal pollution load. UN-ESCWA and BGR (2013) inventoried shared water resources in western Asia including the Karun and Kharkheh basins of Iran and the Tigris River basin generally. Jouladeh-Roudbar *et al*. (2020) observed increasing numbers of abnormalities in fishes over recent years, attributed to pollution, and illustrating scoliosis, lordosis and abnormal fins and barbels in fish from the Leyleh River. A 2015 survey in this river showed about 35% of fish with abnormalities. There is an extensive online literature on this basin, particularly regarding water conflicts and management.

Por and Dimentman (1989) regarded the Tigris-Euphrates or Mesopotamian basin as a cradle for inland aquatic faunas. The basin acted as an area where African and Asian species could meet or transit such as the cichlid *Iranocichla*. Banarescu (1977) and Por and Dimentman (1989) regarded the area to be a zoogeographic crossroads with elements from the Palaearctic such as the cyprinoid genera *Leuciscus* (= *Squalius*) and *Chondrostoma*, Mediterranean genera such as the cyprinoid *Acanthobrama* (although Krupp (1987) referred to this genus as Palaearctic, of Mesopotamian origin), and Oriental genera such as the cyprinid *Garra* and the spiny eel *Mastacembelus*. Borkenhagen (2017a) also considered the Tigris-Euphrates as an important crossroad for colonisation of the Jordan River, the Orontes River and the Arabian Peninsula, the latter colonised by at least two separate events. Al-Rudainy (2008) and Coad (2010) are recent accounts of the fishes in Iraq which encompasses the southern part of the Tigris-Euphrates basin. Smith *et al*. (2014) summarised the status and biodiversity of eastern Mediterranean fishes, and this area includes the Tigris-Euphrates basin, although not Iran specifically, and provided context for problems that the Iranian ichthyofauna faces.

Khalaji-Pirbalouty and Sari (2004) studied the biogeography of amphipod crustaceans in the central Zagros Mountains. They considered habitat diversification and climatic fluctuations to be the principal factors influencing species diversity and endemism in this area, with the mountains acting as a barrier to species distribution. Endemism was evident in lizards, plants and amphipods, as well as fish. Mittermeier *et al*. (2004) placed the Zagros mounatins of Iran in the Irano-Anatolian Hotspot but this also included central Turkey, the Alborz Mountains of northern Iran and the Kopet Dagh range of northeastern Iran, encompassing several basins in terms of fishes which are mentioned only cursorily.

An analysis by Coad (1996d) showed that this basin is mainly Black-Caspian Sea basin in its connections, with minor links to Asia and possibly Africa. Numbers of families, genera and

species shared between the Tigris-Euphrates and neighbouring basins were summarised in this analysis. Relatively few taxa appeared to have made the transition between Asia and Africa or survived subsequent climatic and habitat changes.

Certain families are absent from the Tigris-Euphrates but are found in the Indus and the Nile (Notopteridae, Schilbeidae, Clariidae, Anabantidae, Channidae). These are assumed to be of Gondwanic origin and are separated today by plate tectonic movements. A representative of the Channidae is found in eastern Iran but this species is at the western limit of its range there. Only two families are shared between the three basins but are not found to the north, Bagridae and Mastacembelidae, and the relationships of the two species in these families are with the Indus (Travers, 1984).

At the generic level, some have dispersed into eastern Iran from the Indus and other eastern basins but have not reached the Tigris-Euphrates basin, presumably for reasons of time or lack of suitable environmental conditions, e.g., *Aspidoparia* (= *Cabdio*), *Crossocheilus* (= *Tariqilabeo*), schizothoracines. However, two genera have reached the Tigris-Euphrates (the sisorid catfish *Glyptothorax* and the danionid *Barilius*) and Howes (1982) considered *Cyprinion* to be related to the eastern genus *Semiplotus*. *Barilius* resembles Indus and other eastern species superficially although its relationships have not been fully worked out. Assuming that these taxa dispersed westward from the Indus and the east, the route must be determined. All but *Cyprinion* are absent from much of Iran, including the bagrid *Mystus* and the mastacembelid *Mastacembelus* referred to at the family level above. It is unlikely that rivers of the Tigris-Euphrates basin were once tributary to the Indus when sea levels were lower during glaciations as the Gulf of Oman descends to an abyssal plain at 3,340 m. I suspect, but cannot prove, that these taxa reached the Tigris-Euphrates basin across the Iranian land mass and subsequently became extinct as desiccation increased. Many of the rivers in southern and eastern Iran today are very small, regularly dry up and some are highly saline. They may be unsuitable for these taxa. *Barilius*, it should be noted, appears to prefer, in Asia and the Tigris-Euphrates basin, large lowland rivers and its dispersal across Iran is difficult to envisage by headwater capture (the other genera can be found in small streams at higher altitudes as well as lowland rivers). However, Berg (1940) suggested that fish dispersal across this region was facilitated by the coastal rivers of Iranian and Pakistani Baluchestan being part of a single river system in the Pliocene, since submerged by subsidence. The presence of *Mastacembelus* and *Barilius* in western Iranian basins is attributed to headwater capture and/or colonisation from the Tigris-Euphrates basin when Persian Gulf rivers were tributary to an expanded Tigris-Euphrates basin during lowered sea levels in glacial times. This distribution of these genera is not, therefore, a remnant of the dispersal across Iran from Asia.

At the generic level, only *Garra* is found from the Indus to the Nile and in the Tigris-Euphrates basin. Menon (1964) suggested that *Garra* reached the Tigris-Euphrates basin and Africa in two waves from Asia, the first wave being in the Miocene to the Tigris-Euphrates basin, the second through southern Arabia to Africa during the Pliocene. Karaman (1971) disputed Menon's *Garra* waves based on anatomy and zoogeography. *Garra* presumably dispersed from Asia to Africa via the Tigris-Euphrates basin and the Levant. The apparent continuous distribution of *Garra* across southern Arabia is not borne out in systematic analyses by Krupp (1983). *Garra* (and *Cyprinion*) species of southeastern Arabia are clearly related to southern Iranian species, having crossed the Persian Gulf when it was drained during the Pleistocene and part of an extended Tigris-Euphrates basin. Southwestern Arabian species (and a *Barbus* species) are a mixture of African and Levantine elements. Krupp (1983) found no

evidence in his studies for the Arabian Peninsula serving as a transition area in an exchange of freshwater fishes between Asia and Africa. Hashemzadeh Segherloo *et al*. (2017) used molecular evidence to confirm two invasion events for the Middle East *Garra*.

*Nemacheilus sensu lato* also has a similar wide distribution but is probably polyphyletic and detailed revisionary works are enabling adequate zoogeographical analyses to be made. The systematics of loaches in the Middle East is a contentious subject (Por and Dimentman, 1989). The absence of nemacheilid species from southern Arabia also argues for a dispersal route through the Tigris-Euphrates basin as these cryptic fishes are found today in many small streams throughout Southwest Asia and are unlikely to have been eliminated from southern Arabia through desiccation.

The only Nile (or east African) genus present in the Tigris-Euphrates basin was *Barbus sensu lato*. Certain members of this polyphyletic genus in Southwest Asia are characterised by sharing 6 anal fin branched rays, last dorsal fin unbranched ray a smooth spine, large scales, few gill rakers, high dorsal fin ray counts, reduced barbel numbers, compressed body, and other characters which set them apart from European *Barbus* as a monophyletic group, probably related to east African species (as suggested by Banister (1980)). These former *Barbus* species are found from southwestern Arabia (but not southeastern Arabia), through the Levant and the Tigris-Euphrates basin to rivers at the Strait of Hormuz in Iran. They may represent an African element in the fauna of the Tigris-Euphrates and may reflect the route of the cichlid *Iranocichla* or its ancestor from Africa to the Strait of Hormuz. Bănărescu (1992b) considered African elements in Southwest Asia to be the oldest, of at least Miocene age. However, Borkenhagen (2017b) confirmed that the hexaploid Torini of the Middle East and North Africa comprise the genera *Arabibarbus*, *Carasobarbus* and *Mesopotamichthys*, all with species found in Iran, and *Pterocapoeta* from Morocco. The Torini originated in Indo-Malaya and colonised the Middle East and Africa during the Miocene.

A significant proportion of the families and genera in the Tigris-Euphrates basin are also found in the Black-Caspian Sea basin. Such widespread, northern cyprinoid genera as *Alburnoides*, *Alburnus*, *Aspius* (= *Leuciscus*), *Chondrostoma*, *Leuciscus* and *Squalius* reach their southern limit in the Tigris-Euphrates basin (and neighbouring Iranian basins) suggesting that they reached the Tigris-Euphrates basin from the north.

The presence of the sisorid catfish *Glyptothorax* in the Black Sea basin of Anatolia (Coad and Delmastro, 1985) is a recent event through headwater capture from the Tigris-Euphrates basin and thus far is the only example of a clearly-defined Indus genus reaching the Black-Caspian seas basin. It is probably an example, in reverse, of the colonisation of the Tigris-Euphrates basin in recent times from the Black-Caspian seas basin. Berg (1940) pointed out that the upper reaches of the Tigris-Euphrates basin today lie on a plateau close to the upper reaches of the Caspian Sea basin. Headwaters of a number of Tigris-Euphrates basin rivers interdigitate with the upper reaches of Black-Caspian seas basin rivers, e.g., the Aras River of the Caspian Sea and the Kizilirmak of the Black Sea with the Euphrates near Erzurum and Sivas respectively; the Qezel Owzan of the Caspian Sea with Tigris River tributaries. Headwater capture is common in the Zagros Mountains (Oberlander, 1965) and in Anatolia, and pluvial conditions in the past would have facilitated fish dispersal. Por and Dimentman (1989) mentioned direct connections of a proto-Euphrates with Black Sea and Caspian Sea fluviatile drainages before the Pliocene orogeny which would serve to allow entry of taxa to the Tigris-Euphrates basin. Direct connections were interrupted by the early Pliocene as orogeny, rifting and desertification took hold. Almaça (1990) reviewed possible routes for *Barbus sensu lato* species into Iran and the

Tigris-Euphrates basin from the north via what is now Anatolia and east of the Caspian Sea dating from the early Oligocene. A continuous route for exchange of taxa has been possible since the upper Miocene, almost 12 million years ago. These routes have been variously available down to modern times for *Barbus sensu lato* and other taxa as exemplified by some species being in common between the Black-Caspian seas basin while others are distinct but related at the generic level. Bănărescu (1992b) considered that northern or European elements penetrated to the Tigris-Euphrates basin earlier than Asian ones, and that this partially explains their prevalence. Iranian internal and Persis basins and the Levant showed evident affinities with the Tigris-Euphrates basin. The ichthyogeography of the Levant has been dealt with by Krupp (1987) and will not be reviewed here. Krupp considered that parts of the Levant were colonised separately via branches of the Tigris-Euphrates river system. Iranian basins to the east of the Tigris-Euphrates basin have a very similar fauna to that of the Tigris-Euphrates at the species level. The diversity falls off rapidly with distance (Coad, 1987). Headwater capture in the Zagros Mountains is a possible route for species found in common with the Tigris-Euphrates basin but not in Iranian rivers draining separately to the Persian Gulf.

Between 20 and 15 thousand years ago, the Persian Gulf was dry as water was locked up in ice-caps and sea level was 110-120 m lower than today (Sarnthein, 1972; Kassler, 1973; Nützel, 1975; Al-Sayari and Zötl, 1978; Vita-Finzi, 1978). The floor of the Gulf was then thought to be a generally waterless, flat depression with a few swampy tracts rather than a Garden of Eden as had been proposed. A marine transgression occurred 12-8 thousand years ago caused by the melting of the Laurentide ice sheet and drainage of Lake Agassiz in Canada (Perkins, 2002). By about 11,500 years B.P., the Gulf was filled with present shorelines attained shortly before 6,000 B.P. and exceeded by 1-2 m (Lambeck, 1996). Streams now isolated from the Tigris River basin by the sea in the Persis (formerly Gulf) and Hormuz basins would have been tributary to an extended Shatt al Arab, extending 800 km down the Persian Gulf to form an estuary at the shelf margin in the Sea of Oman, now under 110 m of sea. Earlier regressions no doubt occurred and facilitated the movement of fishes.

Berg (1940) placed this basin in the Mesopotamian Transitional Region, since the boundaries of three zoogeographical regions meet here, namely the Holarctic (i.e., its Palaearctic part), Sino-Indian (= Oriental) and the African (= Ethiopian). The Mesopotamian Transitional Region includes the Tigris and Euphrates basins and the Quwayq River, Syria, forming a single Mesopotamian Province. The province is transitional between the Mediterranean Subregion and the Indian Subregion. Genera such as *Alburnus*, *Aspius* (= *Leuciscus*), *Chondrostoma*, *Leuciscus* and *Squalius* pointed to a Mediterranean or European association while such genera as *Glyptothorax*, *Barilius*, *Mystus* and *Mastacembelus* pointed to an Indian association.

Por and Dimentman (1989) regarded the Mesopotamian subregion or Tigris-Euphrates basin as one of the most isolated major freshwater areas in the world. However, as Coad (1997f) pointed out, endemism is only at the species level and diversity is low.

The Zagros Mountains form the western flank of Iran and store water as snow. The higher peaks are snow-capped even in summer. Zard Kuh, for example, reaches 4,548 m (32°22'N, 50°04'E). Rivers drain south and west to become tributaries of the Tigris River in Iraq or its confluence with the Euphrates River, the Shatt al Arab (known as the Arvand Rud in Iran). The Shatt al Arab has a course of 190 km to the head of the Persian Gulf, is 400-1,500 m wide, and is navigable by ocean-going ships. It forms part of the Iran-Iraq border. The origin of the Tigris River is the Hazar Gölü of Elazig (38°41'N, 39°14'E) between the Murat Nehri and the Euphrates. The Tigris rises only 30 km from the Euphrates River. It flows south-east, forming a

short section of the border of Syria with Turkey, before entering Iraq to parallel, roughly, the course of the Euphrates River. It is a larger and swifter river than the Euphrates because of its left bank tributaries from Iran. The Tigris is over 1,900 km long (1,851 km and 2,032 km are extremes cited in the literature). It is the 81st river in size in the world. The Tigris-Euphrates basin encompasses 784,500 sq km of which 19% or 146,000 sq km lies in Iran (Gleick (1993) gave 238,500 sq km and 27% for Iran and 884,000 sq km for the whole basin; the Iraqi Government in the same publication gave 378,834 sq km for the Tigris basin alone with Iran's share 28.8%). Iran contributes 7% of the water supply of this immense basin.

Khuzestan, Arvand River near Persian Gulf
(Iran Iraq border Arvand Rud 2017, CC BY-SA 4.0, PersianDutchNetwork).

The name Tigris is from the Old Persian "Tigrā", ultimately from the Sumerian "Idigna", whence the species name *Alburnoides idignensis* was formed. Idigna is probably derived from "running water", meaning "swift river", in contrast to the slower and more silt-laden Euphrates. The Persian name is the Arvand Rud or "Swift River", now restricted to the lower reach of the confluent Tigris and Euphrates or Shatt al Arab. Several locations in the southern Tigris River basin of Iran and Iraq are the type localities for *Garra rufa gymnothorax* (= *G. gymnothorax*).

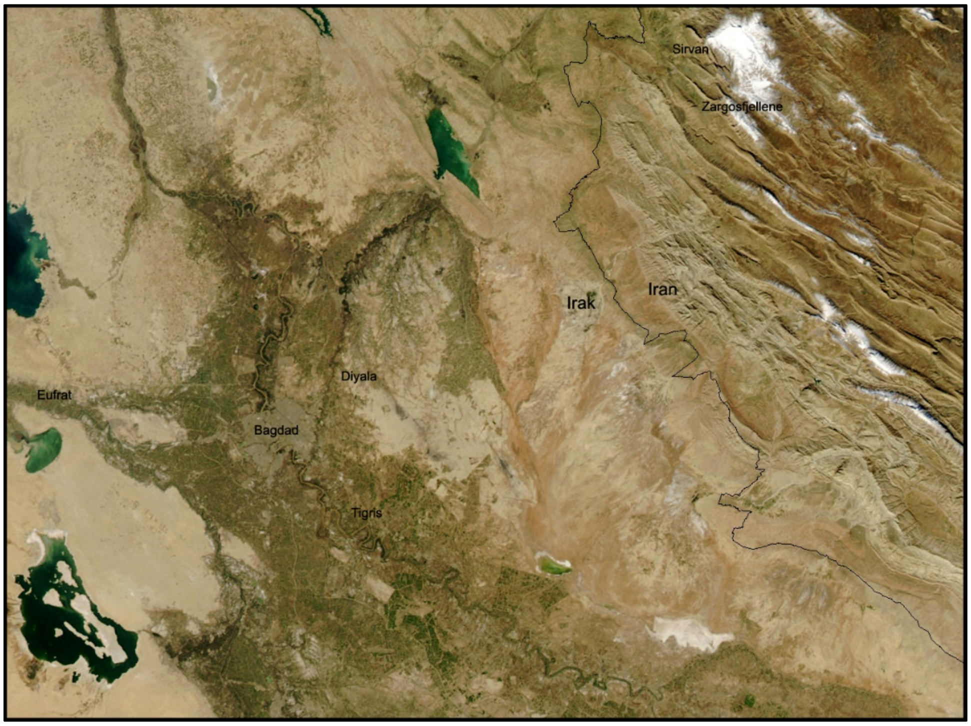
The Tigris is an alkaline river (pH 7.8-8.2) with a total hardness of 200-350 mg/l. Water temperatures generally range from 8.5°C in January to 31.4°C in August. The flow pattern of the Tigris and its tributaries has a sharp peak in April at about 9 billion cu m, falling rapidly to about 1 billion cu m from August to October before beginning to rise again. The water level may fall by as much as 2 m over the summer. Interannual variations in spring flood levels are marked. Approximate stream flows over the past 6,000 years were given by Kay and Johnson (1981) based on proxy data from palaeoenvironmental sources. They found an increase in stream flow over this period. The southern province of Khuzestan in the Tigris River basin with 9% of Iran's surface area has an estimated 37% of its surface water flow. However, water from the Karun River which feeds the Khuzestan plains is being diverted to the Esfahan basin (Zayandeh River) and to Qom, Yazd and Kerman via pipelines (The Guardian, 20 April 2015). The sugarcane industry also extracts large amounts of water, increases salinisation and contributes pesticides to the environment.

Al-Ansari *et al*. (2014) predicted drops in rainfall through climate change in northwest Iraq, and coupled with dams extracting water in Syria and Turkey, expected the Tigris and Euphrates to dry up by the year 2040!

The Shatt al Arab, the confluence of the Tigris and Euphrates rivers, is under tidal influence up to 110 km from the mouth. Its waters are therefore strongly mineralised. Salinity varies with distance from the sea. Crops are irrigated by means of the tidal rise which is used to push fresh water into the fields (Harrison, 1942; Gholizadeh, 1963; Gholizadeh and Fatemi, 1969). Ghadiri (2004) also detailed how water abstraction for irrigation caused reduced water flow and allowed further penetration of seawater. This has obvious effects for the fish fauna and its composition as well as for increased salinisation of habitats. There are appreciable diurnal and seasonal fluctuations in physico-chemical conditions. Tidal waters probably penetrated far inland through the Holocene as evidenced by faunal remains in boreholes of the Hammar Formation (MacFadyen and Vita-Finzi, 1978). Al-Hassan and Hussain (1985) described the hydrological parameters affecting the penetration of marine fishes into the Shatt al Arab. An increase in the Tigris River discharge decreased salinity in the Shatt al Arab; previously marine species were common at Basrah in Iraq but they became rare, *Carassius auratus* appeared in Basrah fish market and *Cyprinus carpio* were caught in large numbers down to the estuary (N. A. Hussain, *in litt*., 1994). Mohamed and Abood (2017a) listed *Carasobarbus sublimus* (presumably in error for *C. luteus*), *Carassius auratus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hemiculter leucisculus*, *Hypophthalmichthys molitrix* and *H. nobilis* from the Iraqi Shatt al Arab, the exotics having a higher impact when environmental degradation was high and water quality declined. Pollution is widespread in the Shatt al Arab from industrial, agricultural and untreated human wastes. Lower reaches were in better condition than upper reaches, water quality having fallen from salt water intrusion as fresh water discharge declined in recent years (Mohamed and Abood, 2017b). Native fishes had very low abundance at sites across from or near Iran, e.g., in cyprinoids *Carasobarbus luteus* at 1.808%, *Leuciscus vorax* at 0.252%, *Alburnus mossulensis* (= *A. sellal*) at 0.187%, *Acanthobrama marmid* at 0.138%, with exotic species *Carassius auratus* at 13.24%, *Cyprinus carpio* at 3.235% and *Hemiculter leucisculus* at 0.481%. Mohamed and Abood (2021) examined the trophic relationships of fish in the Shatt al Arab, their lower station bordering Iran. *Carasobarbus luteus*, *Carassius auratus* and *Cyprinus carpio* were omnivorous species. *C. luteus* fed mainly on algae, insects, macrophytes, detritus and diatoms, while *C. auratus* fed on insects, macrophytes, algae and detritus, and *C. carpio* on insects, macrophytes, snails and detritus. There was dietary overlap between *C. luteus* and *C. auratus*. Hussain *et al*. (2001) evaluated environmental degradation in the Iraqi portion of the Shatt al Arab and its effects on the fish fauna. Mohamed *et al*. (2017) also assessed water quality in the Iraqi Shatt al Arab, upriver from the Iranian part, and also found that *Carassius auratus* was the most abundant fish species. *C. auratus*, with 576 specimens caught, was the second most abundant species (after the cichlid *Oreochromis aureus* at 580 specimens) in the lower Shatt al Arab bordering Iran (Mohamed and Abood, 2021).

There are two principal Iranian tributaries of the Tigris River in the north. The Little or Lesser Zab River (= Zab-e Kuchek) drains a small stretch of mountains south of Lake Urmia including the Kalwi Chay, Iran having 24% (4,747 sq km) of this basin and Iraq 76% (UN-ESCWA and BGR, 2013). The Diyala River (= Sirvan or Sirwan River in Iran) drains the western mountains of Kordestan, Iran having 25% (8,310 sq km) of this basin and Iraq 75% (UN-ESCWA and BGR, 2013). The Sirvan received moderate pollution from rainbow trout fish farms at Palangan (Weisi *et al*., 2019). The water quality of the Garan Dam, 15 km northeast of

Marivan, on the Sirvan River was assessed by Karimian *et al*. (2020) and found to have middle to good levels, presumably suitable for fish, although its water is meant for agriculture and municipal water of Marivan.




Diyala River draining from Iran to Baghdad via Derbendikhan Dam
(CC0, cropped and named by Svart, NASA).

West Azarbayjan, Little Zab River
(CC BY-SA 3.0, Auoob Farabi).


West Azarbayjan, Little Zab River at Berisu, Arash Jouladeh-Roudbar.


Kermanshah, Leyleh and Sirvan rivers
(CC BY 4.0, Ismail Sharifi).


Kermanshah, Sirvan River, after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

Kordestan, Sirvan River at Palangan (CC BY 2.0, Ninara).

Tigris River northern basin
(IranCatchKhF1, CC BY-SA 4.0, Mahdy Jaffar).

The Kalwi Chay is 165 km long and the Diyala River is 442 km long. The Alvand or Alwand River flows west through Qasr-e Shirin and then south to join the Diyala River in Iraq. A principal tributary of the Diyala in Iran is the Qeshlaq River which flows through Sanandaj (35°19'N, 47°00'E). The river is polluted from Sanandaj and from agriculture wastes (Jafari Salim *et al*., 2009). Majnoni *et al*. (2015) found the Gheshlagh (= Qeshlaq) River at Sanandaj was polluted with heavy metals, particularly cadmium and lead. Abdi and Yasi (2015) described construction of three dams and an inter-basin transfer of water from the Zab River to the Lake Urmia basin, including ecological needs of key riverine species such as *Barbus capito* (*sic*, not a Zab River species).

Kermanshah, Alvand River at Qasr-e Shirin, Arash Jouladeh-Roudbar.

Kordestan, Qeshlaq River east of Sanandaj (cropped, CC BY-SA 4.0, Edriss Bahrampour).

A number of minor streams and small rivers also cross the Iran-Iraq border, e.g., the Meymeh River, see below, but the principal rivers in the south drain through anticlines in spectacular gorges or tangs, funneling the waters of the Zagros onto the Khuzestan plains through a narrow gap near Dezful (32°23'N, 48°24'E). Stream flows in late winter are at least 10 times that of summer and 116,500 sq km of mountains and three big rivers debouch onto 38,800 sq km of plain. Lowlands may be inundated for more than 100 days. Early accounts of floods in Mesopotamia, dating back to Sumerian times almost 5,000 years ago, are discussed by Mallowan (1964). Floods can encompass close to 100,000 sq km in Iran and Iraq at the head of the Persian Gulf (Naff and Matson, 1984). Progressive clearing of woodland over the last 7,000 years increased runoff, causing higher and more severe floods, soil erosion, increased turbidity in streams and higher sedimentation (Wagstaff, 1985). Erosion is three times the world standard rate at 30 tonnes/hectare and would rise twofold over the next 10 years (*Islamic Republic News Agency*, 20 December 1998). All these must have, and continue, to affect the fishes in this and other basins, favouring those species able to cope with these conditions. Even artificial habitats such as small dam reservoirs in Chahar Mahall and Bakhtiari Province are affected by high sedimentation rates and their utility as fish habitat must be lessened (Mousavi and Samadi-Boroujeni, 1998).

The main river in the south is the Karun, with a catchment of 67,340 sq km (Naff and Matson, 1984) and a length of 890 km. A straight line between the source and the mouth is only about 250 km, showing a very meandering course. UN-ESCWA and BGR (2013) gave a brief overview of the Karun River basin, noting severe pollution and giving details of dam construction.

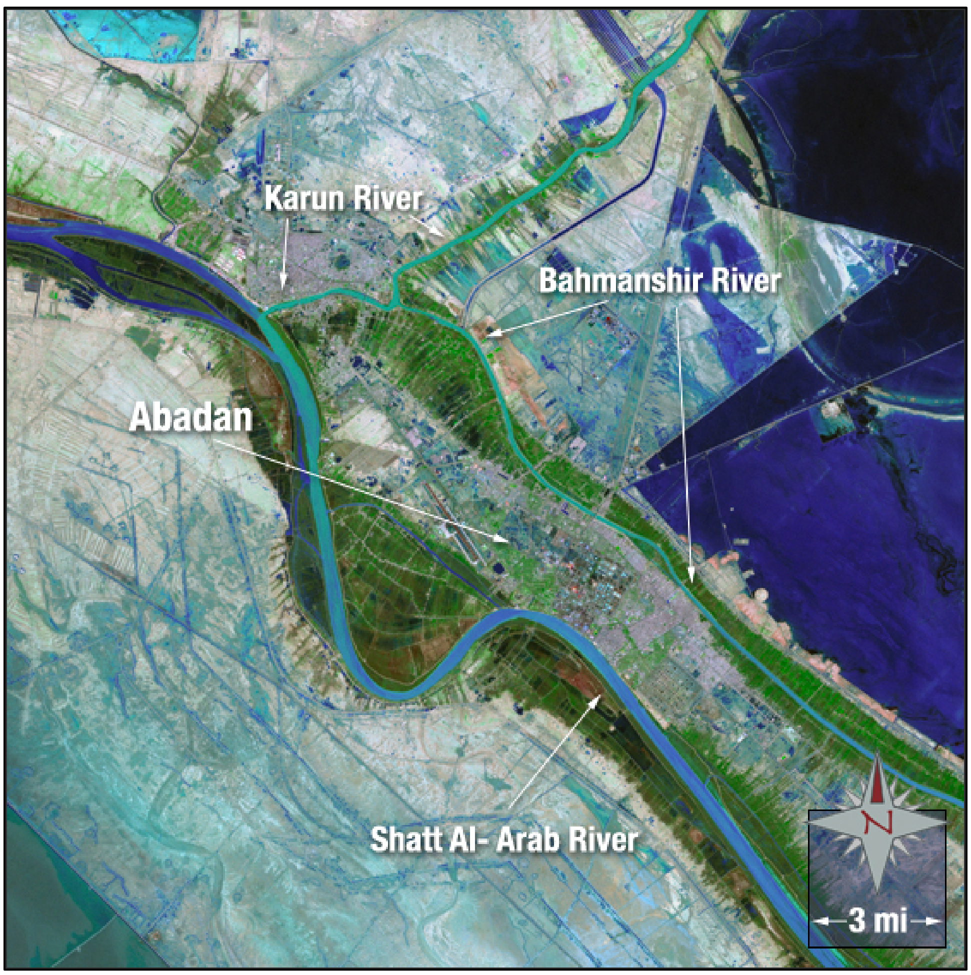
Karun River basin
(IranCatchKhF3, CC BY-SA 4.0, Mahdy Saffar).

The river now drains to the Shatt al Arab but once drained directly into the Persian Gulf. The Karun is also connected to the Gulf via the Bahmanshir River, 70-80 km long in a channel 500-800 m wide, paralleling the Shatt al Arab, and enclosing Abadan Island. The Bahmanshir is the only river along the Persian Gulf coast to have a significant fishery. A physicochemical study of the Bahmanshir was carried out by Faal (2009). The water temperature and pH changed from 13.2 to 27.5°C and from 7.2 to 8.7 respectively. The minimum and maximum dissolved oxygen values were 5.4 and 1l.9 mg/l respectively. The results indicated that the amount of nutrients such as nitrate, nitrite, and ammonia were relatively low in the Bahmanshir River. Sakhaei *et al*. (2018) assessed the river health as declining.

Khuzestan, Karun River with testy water buffalo, no cyprinoids near shore, only the mugilid *Planiliza abu*, 25 January 1978, Brian W. Coad.

Khuzestan, Karun River near Razzij
(Neyzar and Karun River …., in Farsi, CC BY 3.0, Matin Fattahi ).

Khuzestan, Karun River north of Ahvaz
(Khuzestan Province, Iran - panoramio, CC BY 3.0, Seyed Mahmoud Javadi).




Khuzestan rivers
(CC0, NASA GSFC Landsat LDCM EPO Team).

Khuzestan, Bahmanshir River at Tangeh-Se, no cyprinoids near shore, only the gobiid *Boleophthalmus dussumieri*, 23 November 2000, Brian W. Coad.

Khuzestan, Bahmanshir River, bridge at Istgah-e Haft, Abadan (Istgah e Haft Bridge Abadan Iran (1), CC BY-SA 4.0, Ahmad Darabi).

The Karun has the greatest mean discharge, followed by the Dez and Karkheh rivers in this basin. The Karun mean discharge is the largest in Iran. In the early 20th century, the discharge was from a minimum of 280 cu m/sec to the flooding rate of 3,700 cu m/sec. The Karun carries a heavy silt load with a hundredfold increase during flood. The Karun discharge now ranges from 207 cu m per second to 2,225 cu m/sec, average 1,100 cu m/sec, while the Dez is 63-1,227 cu m/sec, average 288 cu m/sec. The Jarrahi (see below) range is 8-770 cu m/sec,

average 78 cu m/sec. These figures vary among different sources indicating fluctuations between years and gauging stations; however, the relative importance of these rivers is shown. The peak discharge of the Karun is in April, with high values also in March and May; the lowest discharge is in October when flow is only about a ninth of the peak. The combined Tigris-Euphrates-Karun in flood carries five times the load of the Nile (Fisher, 1968). Most of this is deposited north of Basrah (30°30'N, 47°47'E) and much is lost to evaporation in the marshes, e.g., of 27 cu km of discharge into the Persian Gulf through the Shatt al Arab, 22 cu km is from the Karun River. 22 million metric tons of dissolved chemicals are deposited each year and hence there are siltation and salinity problems in the lower parts of this basin. Ghadiri (2014) detailed salinisation of the Karun by seawater encroachment as water is abstracted upriver for irrigation of crops and domestic use, and by shallow, saline, groundwater intrusion. Conductivity at Shushtar, Ahvaz and Khorramshahr/Abadan was 1.5, 2.5 and 3.5 dS/m, total suspended solids 960, 1,620 and 2,240 p.p.m., $Cl^{-1}$ 315, 516 and 849 p.p.m., $SO_4^{-2}$ 125, 350 and 450 p.p.m., hardness 246, 526 and 626 p.p.m., biological oxygen demand 2.0, 3.0 and 3.5 p.p.m., and chemical oxygen demand 10, 18 and 16 p.p.m. Fakouri *et al*. (2019) presented management scenarios for control of salinity due to low flow rates and increased loading of pollutants. Ansari and Akhoonzadeh (2020) used the Landsat-8 satellite to map Karun River salinity caused by severe climate conditions and regional physiography, industrial sources, domestic and urban sewage, irrigation of agricultural land in particular cane sugar fields, fish hatcheries, hospital sewage, and the high tide level of the Persian Gulf.

The Shushtar Historical Hydraulic System on the Karun River is a UNESCO World Heritage Site dating back to the 5$^{th}$ century B.C.

Khuzestan, Shushtar Historical Hydraulic System Panorama
(CC BY-SA 4.0, Iman Yari).

Khuzestan, Karun River at Shushtar
(Shushtar, CC BY-SA 3.0, Hosein-hidalo).

Khuzestan, Karun River at Shushtar Canyon discoloured by spring rains
(Shushtar Canyon, CC BY-SA 2.0, Ninara).

The Karun River on the Khuzestan plains was examined in 1992 for various parameters and at various localities (courtesy of the Iranian Fisheries Research and Training Organization, Ahvaz). It had a pH of 7.07-8.85, mean 8.17, dissolved oxygen 5.6-12.38 p.p.m., mean 9.29 p.p.m., bicarbonate 79.3-214.72 p.p.m., mean 154.4 p.p.m., carbonate 0.6-21.0, mean 5.53 p.p.m., total alkalinity 1.9-3.8 meq/l, mean 2.84 meq/l, carbonate hardness 5.32-10.64 p.p.m., mean 7.95 p.p.m., total hardness 168-474 p.p.m., mean 287 p.p.m., ash residue 40-142 p.p.m.,

chloride 45.4-518.3 p.p.m., mean 207.28 p.p.m., total dissolved solids 226-1,374 p.p.m., mean 696 p.p.m., sulphate 43.75-325.0 p.p.m., mean 101.73 p.p.m., calcium 33.63-101.7 p.p.m., mean 61.8 p.p.m., magnesium 16.8-78.24 p.p.m., mean 33.8 p.p.m., phosphate 0.05-4.0 p.p.m., mean 0.24 p.p.m., iron trace to 0.32 p.p.m., mean 0.069 p.p.m., manganese trace to 0.657 p.p.m., mean 0.483 p.p.m., and nitrate trace to 0.657 p.p.m., mean 0.039 p.p.m. Esmaili *et al*. (1999) reported heavy metals in water, sediments and fish from the Karun River and Jafarzadeh-Haghiehi *et al*. (2005) reported on the poor water quality of the river. Haghighi and Arabi (2010) modeled water exploitation of this river for fish farms, tracing heavy metal pollution and concluding where water could be safely withdrawn. Dadolahi-Sohrab and Arjomand (2011) examined stations in the Karun for the effects of effluent from the Khorramshahr soap factory. Parameters such as chemical oxygen demand, biological oxygen demand and chlorine exceeded acceptable levels although the river showed a high ability for dilution of the effects. Zarei and Pourreza Bilondi (2013) studied the water quality of the Karun River and found that variations were mostly affected by varying discharge and the input of dissolved mineral salts from geological formations along the entire river. Hosseini-Zare *et al*. (2014) surveyed 24 agricultural, 38 urban and nine industrial wastewater discharges in the Karun River drainage basin and found that agricultural activities had the higher risk of degrading the river water through salinity and increased load of soluble salts. The Dez River had organic pollution based on chemical oxygen demand from the sugarcane industries while the city of Ahvaz was a major centre of organic pollution based on biochemical oxygen demand and ammonia and microbial pollution loads. Behmanesh (2020) evaluated water quality in the Karun River and it was found to be suitable for fish farming in terms of pH, temperature and total dissolved solids but was unsuitable for dissolved oxygen, water turbidity and heavy metal load.

Askary Sary and Velayatzadeh (2014a) reported on arsenic levels in muscle and liver of fish from the Karun River (*Barbus* (= *Carasobarbus*) *luteus*, *Cyprinion macrostomus*, *Aspius* (= *Leuciscus*) *vorax*) finding the highest levels in the first species and exceeding acceptable levels in liver in all species. Askary Sary and Karimi Sari (2014a) examined iron levels and hazard quotient in the farmed fish *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Aristichthys* (= *Hypophthalmichthys*) *nobilis* from the Azadegan Warm Water Fish Culture Centre in Khuzestan, finding no differences between these species and marine fishes, and the hazard quotient was less than one and so carried no risk for human consumption. Askary Sary and Velayatzadeh (2014b) examined lead and zinc levels in *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix* and *Aristichthys* (= *Hypophthalmichthys*) *nobilis* from fish farms at Ahvaz and found levels were generally within international standards. Askary Sary and Mohammadi (2015) studied arsenic at the Warm Water Fish Culture Centre and found concentrations were the same in muscle and liver of *C. carpio* and *H. molitrix*, significant differences were between tissues in *H. nobilis* and *C. idella*, and the highest concentration was in *H. nobilis* at 0.31mg/kg and the lowest in *H. molitrix* at 0.177 mg/kg.

Soleymani *et al*. (2015) investigated fish abundance at Ahvaz on the Karun River finding *Cyprinion* sp. (probably *C. macrostomus*) (16%), farmed carp (presumably *Cyprinus carpio*) (16%), *Aspius* (= *Leuciscus*) *vorax* (14%), white carp (species unclear, 14%) and *Barbus pectoralis* (probably *Luciobarbus barbulus*) (12%), varying with season. Taghavi Niya and Velayatzadeh (2015) described the fish fauna of the Shour (= Shur, or salt) River which enters the Karun River above Shushtar. Cyprinoidei with nine species had the highest frequency (80.9). *Capoeta trutta* was the most dominant species in all stations and *Capoeta trutta*, *Cyprinion macrostomus*, *Liza* (= *Planiliza*) *abu* (abu mullet) and *Cyprinion kais* with 41.7, 19, 16.7 and

8.4% were the most frequent species, respectively. The most frequent species in sample stations one to three was *Capoeta trutta* with 47.2%, 40.0% and 32.3%, respectively. Salinity varied from 1.91 to 7.18‰. The Abshur or Ab-e Shur River is the type locality of *Garra tiam*.

CMNFI 2008-0173, Khuzestan, Ab-e Shur, 30 November 2000, Brian W. Coad.

Zare *et al*. (2019) and Zare Shahraki *et al*. (2020) studied the fish communities of the Karun River at 53 sites and found the fauna was dominated by cyprinids (about 65%; mainly *Capoeta coadi*, *Garra rufa*, and *Capoeta aculeata* (= *C. macrolepis*)). *Capoeta coadi* was the most abundant species in most studied sites. The cyprinoid species were *Acanthobrama marmid*, *Alburnus caeruleus*, *Alburnus doriae*, *Alburnoides idignensis*, *Alburnus sellal*, *Arabibarbus grypus*, *Barbus karunensis*, *Barbus lacerta*, *Barilius mesopotamicus*, *Capoeta aculeata* (= *C. macrolepis*), *Capoeta coadi*, *Capoeta trutta*, *Carasobarbus kosswigi*, *Carasobarbus luteus*, *Carassius gibelio*, *Chondrostoma regium*, *Cyprinion macrostomum*, *Cyprinus carpio*, *Garra rufa*, *Hemiculter leucisculus*, *Luciobarbus barbulus* and *Squalius berak*. Sites ranged from small high-altitude creeks to large lowland rivers, the latter often affected by various anthropogenic pressures. Pristine abiotic conditions were mainly restricted to small high-altitude sites, which had low chemical pollution and excellent habitat features (in particular with low fine sediment deposition, natural channel morphology and intact riparian vegetation).

The Karun headwaters are extensive and lie near both the Esfahan and Kor River basins. The Armand, Bazoft, Beheshtabad, Beshar (or Bashar) and Khersan rivers are important headwater tributaries of the Karun River. The Beshar River is the type locality of *Barbus karunensis* and *Capoeta coadi*. The Ab-e Shalamzar is a tributary of the Khersan River. The Bibi-Sayyedan River flows southwestward from the heights of the central part of the Zagros Mountain, joining the Marbor River and thence the Khersan River. Boustani *et al*. (2011) and Raeisi *et al*. (2010) examined *Cyprinus carpio*, *Carassius auratus gibelio* (*sic*), *Alburnus alburnus* (possibly *A. hohenackeri*) and *Capoeta aculeata* (= *C. macrolepis*) from the Beheshtabad River. They found cadmium and lead levels in the flesh exceeded acceptable levels in some cases, attributing the presence of heavy metals to the misuse of phosphate fertilisers in

agriculture. Najafi *et al*. (2021) found that levels of arsenic, cadmium, chromium, copper, lead and zinc in the Beheshtabad River were natural and not from pollution. Aalipour *et al*. (2019) examined the diet of the exotic rainbow trout, *Oncorhynchus mykiss*, in the Beheshtabad River and found Crustacea, Insecta, Gastropoda and Teleostei were important throughout the year. Teleostei included Cyprinidae (= cyprinoids). Rahimi *et al*. (2011) evaluated the water quality and pollution of the Beshar River from upstream to downstream of Yasuj. Biological oxygen demand was at a minimum (1.7 p.p.m.) above the city and dissolved oxygen at a maximum (8.45 p.p.m.), these values worsening at the city and recovering below as pollutants degraded and diluted. Yazdanpanah *et al*. (2017) studied seven stations in the Ganjegan River of the Beshar River basin, and recorded pollutant effects from rainbow trout (*Oncorhynchus mykiss*) farms. Bagheri *et al*. (2018) described water quality parameters for the Parvaz and Sabzkoh rivers in the upper Karun River basin as part of planning rainbow trout farms. Soluble phosphate was higher than acceptable standards and nitrite and malachite green would also have to be monitored and controlled.

Climate change was predicted to have effects on snowmelt runoff of the Karun basin (Ghorbanizadeh Kharazi *et al*. (2010). In the period 2000-2050, peak runoff was expected to shift from spring to winter, summer flow would decrease slightly and autumn would not change considerably. Spring flow is important for fish spawning.

Karun River basin
(CC BY-SA 4.0, Shannon1).


Chahar Mahall and Bakhtiari, Armand River
(WV banner Chaharmahal and Bakhtiari province Armand River, CC0, SAMIN).

Chahar Mahall and Bakhtiari, Armand River near Sharak-e Sunk
(Rudkhaneh Armand Sunak …., in Farsi, CC BY 3.0, mehrdadmorano).

Chahar Mahall and Bakhtiari, Bazoft River
(CC BY-SA 4.0, Boboszky).

Chahar Mahall and Bakhtiari, Bazoft River
(Bazoft river snow, CC BY-SA 4.0, Bazofti).

Chahar Mahall and Bakhtiari, Beheshtabad River, Soheil Eagderi.

Chahar Mahall and Bakhtiari, Beheshtabad River, Yazdan Keivany.


Kohgiluyeh and Bowyer Ahmad, Beshar River, Hamid Reza Esmaeili.


Khersan River
(CC BY 4.0, *Tasnim News Agency*, 2 December 2018).

Kohgiluyeh and Bowyer Ahmad, Khersan River at Atishgah, Arash Jouladeh-Roudbar.

The Dez River or Ab-e Dez is a mid-course Karun tributary and is 400 km long. Its flow is 140 cu m/sec in the driest months and approximately 610 cu m/sec in the spring (Encyclopædia Iranica, www.iranicaonline.org/, downloaded 10 July 2016). Aghasi *et al*. (2014) found Dez River water from nine stations from the Dez Dam to the Karun River conjunction was lower in quality than the Tajan River in Mazandaran and in comparison with rivers in other countries. Mohammadi Rouzbahani *et al*. (2015) used a benthic index of biotic integrity to assess river ecological quality and found most sites to be in poor condition. Ebadati (2017) examined 394 samples and found most Dez River water quality parameters were within permissible ranges. Mortazavi and Norozi Fard (2019) measured concentrations of cadmium, copper, lead and zinc in sediments and in *Capoeta trutta*, *Carasobarbus luteus*, *Chondrostoma regium* and *Luciobarbus pectoralis* (probably *L. barbulus*). Conditions were unfavourable for fish and high cadmium levels were atrributed to effluent from farmlands. The Dez River was stocked with 10,000 shabout (*Arabibarbus grypus*) and 5,000 common carp (*Cyprinus carpio*) (https://financialtribune.com/, 24 July 2017).

The Sezar River is a tributary in the upper Dez River basin and is the type locality of *Capoeta pyragyi*. The Loven cave fish locality is in the Sezar River basin and is the type locality for *Garra lorestanensis* and *G. typhlops*.

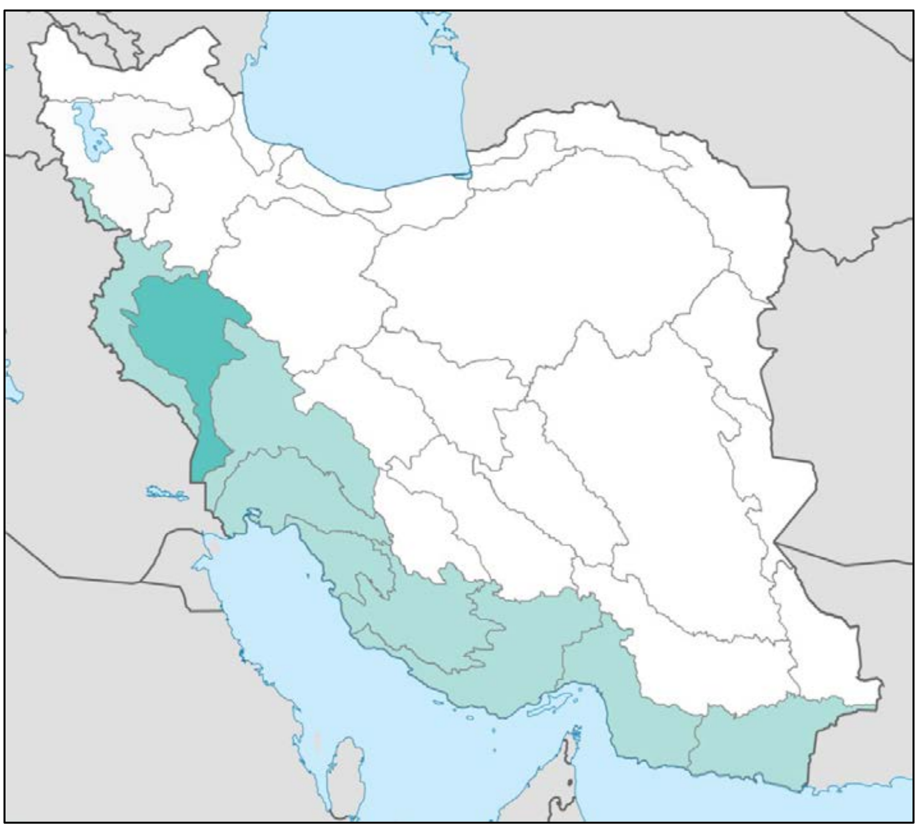
Khuzestan, Dez River at Dezful, 3 December 2000, Brian W. Coad.

Habitat of *Alburnoides idignensis*, *Barilius mesopotamicus*, *Cyprinion macrostomus* and *Garra rufa*, CMNFI 2008-0165, Khuzestan, Dez River branch near Shush, 24 November 2000, Brian W. Coad.


Lorestan, Sezar River in upper Dez River basin near Tang-e Haft,
4 December 2000, Brian W. Coad.

The Karkheh River (with the Cherdavel, Dinorab, Kahman, Kashkan, Qareh Su, Gamasiab and Simareh or Seymareh in its upper reaches) is 755 km long, but is lost in the Hawr al Azim marshes of the Tigris after draining 51,324 sq km (Marjanizadeh *et al*., 2009) or 117,000 sq km (Encyclopædia Iranica, www.iranicaonline.org/, downloaded 10 July 2016), the difference presumably based on inclusion or not of tributaries and sub-basins. Sutcliffe and Carpenter (1967) described runoff from the Karkheh basin. There is a delayed flow-off, with its peaks in late spring and early summer being the most important, as a result of snow melt on the Zagros Mountains.

Kermanshah, Dinorab River, Bisotun, shortly before confluence with Gamasiab River
(CC BY-SA 2.0, Ensie & Matthias).



Karkheh River basin
(IranCatchKhF2, CC BY-SA 4.0, Mahdy Saffar).

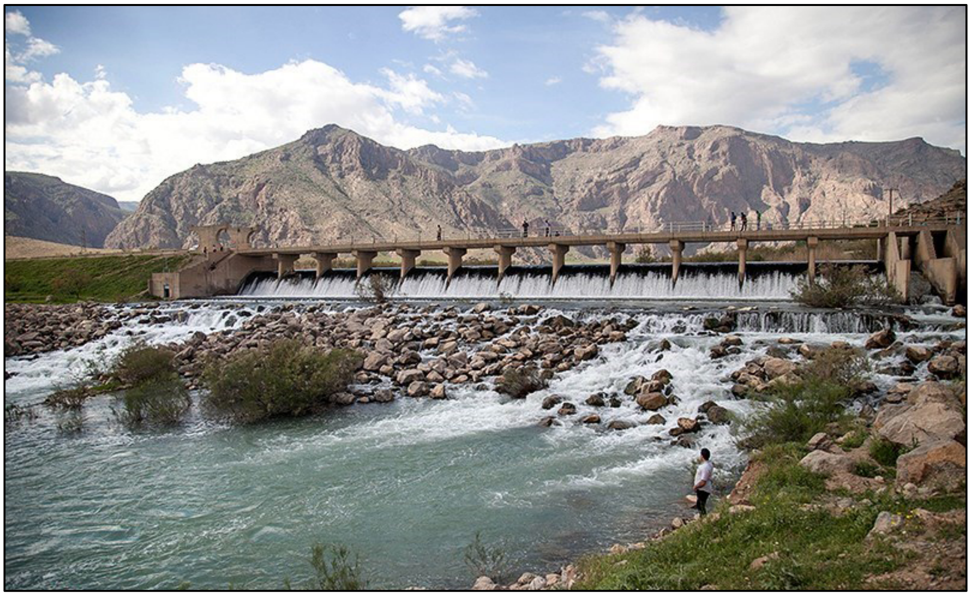
The Karkheh is the third longest river in Iran after the Karun and Sefid rivers. Haghiabi and Mastorakis (2009) detailed water management in the Karkheh River basin and showed the hydrographical network. The Karkheh and Dez flows were depleted by 70% in 2001 during a drought and it was thought that these rivers might dry completely (Foltz, 2002). The marshes along the Karkheh and Dez rivers, with oxbow lakes and riverine forest, are a habitat now rare in southern Iran and Iraq outside protected areas. The severe drought of the year 2000 dried up the natural Dez reservoirs south of Dezful (*Islamic Republic News Agency*, 29 July 2000). Marjanizadeh *et al*. (2009) gave details of water use and development in the Karkheh River basin with mean annual discharges at various sub-basin gauging stations, effects of drought on stream flows and other data relevant to an arid river basin and its exploitation. UN-ESCWA and BGR (2013) gave a brief overview of the Karkheh River basin and noted the basin ranks third in terms of surface water use in Iran and fourth in groundwater use. Water quality deteriorates downstream including increased salinity from agriculture. Janadeleh and Kardani (2016) measured the concentrations of the heavy metals cadmium, copper, lead, nickel, vanadium and zinc in the muscles, liver and gills of *Barbus* (= *Arabibarbus*) *grypus* and *Cyprinus carpio* (and the mugilid *Planiliza abu*) in the Karkheh River. Occasional consumption was not likely to be a problem but the hazard index for *Cyprinus carpio* was 1.751 which could cause adverse effects with continuous and excessive consumption.

Habitat of *Acanthobrama marmid* and *Barilius mesopotamicus*,
CMNFI 1979-0377, Lorestan, Karkheh River north of Andimeshk,
29 January 1978, Brian W. Coad.

Lorestan, Karkheh River at Kashgan Bridge
(Kashgan Bridge, Iran1, CC BY 3.0, Kazem Fattahi).

Some literature refers to the Seymarreh-Karasu-Gamasiab (and variant spellings) as an important complex of rivers. These are the Simareh, Qareh Su and Gamasiab or Gav Masiab in gazetteers. The Gamasiab joins the Qareh Su and becomes the Simareh which eventually joins the Karkheh River in Khuzestan. A stream in the Simareh River basin is the type locality for *Alburnoides nicolausi*. The Gamasiab is the type locality of *Capoeta shajariani*. The Gav Masiab name may derive from spring-head or cave (gamasab), derived from ga (cow) and masab (fish) in reference to a mythical story about two statues of a cow and a fish in Nahavand erected to ward off disease, or from ga (big), masi (fish) and ab (water), or from gamasi (calm water or river) (Marjanizadeh *et al*., 2009). Gamasiab is used here as it is the most common form in fish literature. The Bid Sorkh River in the Gamasiab River basin is the type locality for *Alburnoides idignensis*.

Biokani *et al*. (2011) reported on the ichthyofauna of the Gamasiab River and recorded the cyprinids *Barbus barbulus* (= *Luciobarbus barbulus*), *Barbus esocinus* (= *Luciobarbus esocinus*), *Barbus grypus* (= *Arabibarbus grypus*), *Barbus lacerta*, *Barbus luteus* (= *Carasobarbus luteus*), *Barbus rajanorum* (identity uncertain), *Capoeta aculeata* (presumably *C*. *macrolepis*), *Capoeta angorae* (not in Iran), *Capoeta damascina* (identity uncertain), *Capoeta macrolepis*, *Capoeta trutta*, *Capoeta umbla*, *Cyprinion macrostomum*, *Cyprinion watsoni* (not in this part of Iran), *Garra rufa*, *Tor grypus* (= *Arabibarbus grypus*, see above) and the leuciscids *Chalcalburnus mossulensis* (= *Alburnus sellal*), *Chondrostoma nasus* (presumably *C*. *regium*) and *Leuciscus cephalus* (= *Squalius berak*). Cyprinoids dominated at 80% of the fish species as listed. Industrial pollution limited the distribution of fishes.



Kermanshah, Gamasiab River
(Gamasiab River 2020-04-29 17, CC BY 4.0, cropped,
Tasnim News Agency, Farzad Menati).

Hosseinpour *et al*. (2018) briefly summarised parasites in fishes in from the Seymareh (= Simareh) River, Lorestan. Species examined were *Capoeta damascina* (= *C*. *shajariani*), *Capoeta trutta*, *Cyprinion macrostomus*, *Garra rufa*, *Tor* (= *Arabibarbus*) *grypus*) and *Carassius auratus*. The fish were infected with monogeneans, digenean trematodes, copepods, cestodes and acanthocephalans. The highest frequency was observed for *Dactylogyrus* (15%), followed by *Gyrodactylus* (9%), *Lernaea* (4%), *Ligula* (2%), acanthocephalans (1%), and *Hemiurus appendiculatus* (1%). The latter species was reported for the first time in freshwater fish in Iran. All species of fish, except *Garra rufa*, were infected with helminth parasites. Zoonotic parasites, such as *Anisakis* were not observed.

Reyahi Khoram and Nafea (2011) surveyed Gamasiab water quality in Nahavand and found that nitrate levels increased downriver, dissolved oxygen was stable, air temperature changes had no effect on dissolved oxygen, and water quality was equivalent to standards of the Department of the Environment. Danesh Pajooh *et al*. (2016) documented the significant effects of four (of 24) *Oncorhynchus mykiss* (rainbow trout) farms on water quality of the Gamasiab. Mansouri *et al*. (2016b) measured the levels of the heavy metals cadmium, chromium, copper, lead and zinc in the gill, liver and muscle tissues of *Capoeta trutta*, *Cyprinus carpio* and *Ctenopharyngodon idella* from the Gamasiab. The hazard quotients were less than 1.0 indicating consumption of these fish was harmless. However, seasonal monitoring was recommended because of bioaccumulation.

Lorestan, Simareh River north of Gardaneh-ye Sar Gach
(Seymareh River, Zagros Mountains, Lorestan Province …., CC BY 3.0, Mahdi Kalhor).

Lorestan, Simareh River
(Seymareh River 01, CC BY 3.0, sharpened, Mahdi Kalhor).

Lorestan, Simareh River
(Seymareh Bridge …., CC BY 3.0, Mahdi Kalhor).

The Qareh Su near Kermanshah is about 30 m wide and less than a metre deep at its deepest. The Qareh Su or black water derives its name from its transparency over a dark, pebbly bed, distinguishing it from the muddy rivers of the lowlands. The Qareh Su is the Classical Choaspes, the water of which the ancient monarchs of Persia carried with them on their military expeditions for its taste, a superiority confirmed by Buckingham (1829). Mansouri *et al*. (2016a) investigated the concentration of heavy metals in the gill, liver and muscle tissues of *Capoeta trutta*, *Ctenopharyngodon idella* and *Cyprinus carpio* and in the Qareh Su. The average concentrations of cadmium, lead, chromium, copper and zinc in the muscle tissue of *Cyprinus carpio* and *Capoeta trutta* were 0.001 and 0.001, 0.016 and 0.008, 0.14 and 0.14, 0.53 and 0.33, and 0.51 and 0.51 mg/g wet weight, respectively. The accumulation of metals in the tissues of liver and gills was found to be higher than that in the muscles. The fish species studied were considered healthy to use.

Kermanshah, polluted Qareh Su near Kermanshah
(cropped, CC BY 4.0, Nasrin Tohidizadeh).

The Kupal or Kopal River east of Ahvaz is a river on the Khuzestan plain (see under *Alburnus sellal* for habitat photograph). Emamgholizadeh (2008) assessed its water quality and found it unsuitable for drinking and agriculture. Total dissolved solids had a range of 1,712-9,728 mg/l, conductivity 2,265-14,520 mmhos/cm, pH 7.3-8.5, potassium 0.0-0.6 meq/l, sodium 3.8-80.0 meq/l, magnesium 1.8-33.3 meq/l, calcium 14.5-41.5 meq/l, sulphate 4.8-68.0 meq/l, chlorine 3.5-78.0 meq/l, bicarbonate 0.9-4.0 meq/l and carbonate 0.0-0.6 meq/l.

The Jarrahi River is a southern Karun tributary from the east. The Marun River is a major Jarrahi tributary. The Marun and Jarrahi feed the Shadegan Marshes, the largest Iranian wetland according to Kurdistani and Bajestan (2004).

Head of Persian Gulf showing the Arvand or Shatt al Arab River (central),
and Jarrahi River entering Shadegan Marshes from the east
(ISS053-E-127540 - View of Iran, cropped and adjusted, CC0, NASA).

Tabari *et al*. (2011) documented long-term variations in Marun River water quality, finding parameters were negatively correlated with river discharge. Mosavi Dehmordi *et al*. (2017) found water quality decreased downstream and recorded limnological and biological features of the river. Sampling in the Marun River in 2000 (see below) found a diverse fish fauna attributed by local colleagues to wastewater rich in nutrients from Behbehan. Cyprinoids included nine species namely *Acanthobrama marmid*, *Alburnoides* sp., (presumably *A. idignensis*), *Alburnus sellal*, *Capoeta damascina* (*sic*), *Carasobarbus luteus, Carassius auratus, Cyprinion macrostomus*, *Cyprinus carpio* and *Garra rufa,* along with *Gambusia holbrooki* (eastern mosquitofish), the spiny eel *Mastacembelus mastacembelus* and a nemacheilid. Asefi and Zamani-Ahmadmahmoodi (2015) assessed the mercury concentrations in muscle tissue of *Arabibarbus grypus* and *Carasobarbus luteus* from the Marun River, finding an average of 0.16 mu g/g wet weight for the former and 0.08 mu g/g for the latter, without any correlation with age, sex and length, and at levels not posing a risk to average consumers.

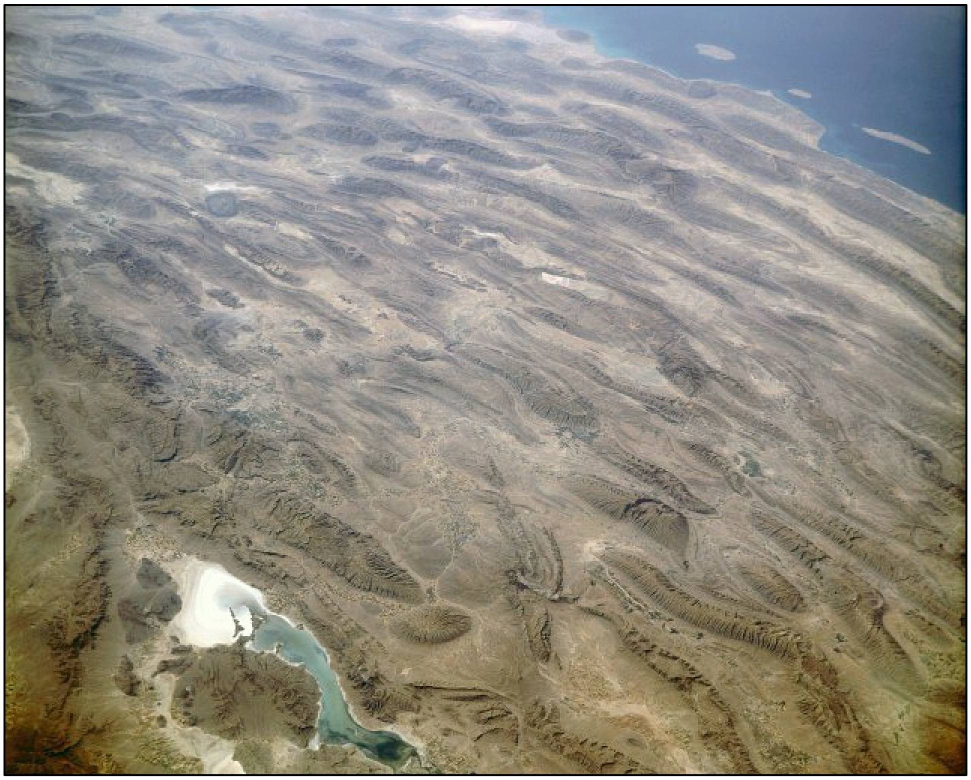
The A`la River in the upper Jarrahi River basin is the type locality for *Barbus sublimus* (= *Carasobarbus sublimus*).

Khuzestan, Jarrahi River,
(Jarahi River, CC0, Elph).

Polluted habitat of *Acanthobrama marmid*, *Alburnoides idignensis*, *Alburnus sellal*, *Capoeta* sp., *Carasobarbus luteus*, *Carassius auratus*, *Cyprinion macrostomus*, *Cyprinus carpio* and *Garra rufa*, CMNFI 2008-0163, Khuzestan, Marun River near Behbehan, 21 November 2000, Brian W. Coad.

Habitat of *Cyprinion macrostomus*, CMNFI 2008-0179, Khuzestan, Marun River at Tang-e Khitab, 21 November 2000, Brian W. Coad.

The Zagros Mountains consist of tightly packed ranges in the Tigris River and Persis basins trending north-west to south-east. A trellis drainage pattern is imposed on this. The tangs, their formation and the drainage pattern are described by Harrison (1937) and Oberlander (1965, 1968a). These deep defiles may exceed 2,400 m in depth with vertical walls of 300 m splitting anticlinal mountain ranges instead of taking apparently easier routes around their ends. They may well be barriers to the movement of less vagile fish species or a highway into the interior for those with some dispersal ability. Tangs formed because an antecedent drainage over lower relief was gradually uplifted at a rate slow enough to permit streams to cut through ridges and retain the original pattern of drainage once the softer material was washed out of the valleys between the anticlines.



Zagros Mountains, Lake Bahktegan at left, Kor River basin, to show tightly-packed ranges in the Persis basin (CC0, NASA).

The uppermost parts of the basin show evidence of headwater captures and this orogenic zone is very unstable. The divide between endo- and exo-rheic basins is not the snowline of the Zagros but is east of it, so streams must first cross the Zagros peaks to start on their journey to the Persian Gulf.

Springs are important in the mountains, tapping aquifers and helping to maintain river flow. The Karun River traditionally has its source in springs. Keivany *et al*. (1992) surveyed 72 springs in Chahar Mahall and Bakhtiari Province, in the upper Karun River basin, and found them suitable for trout culture with a potential production of about 6,000 tonnes per year. Flows varied from 50 to 4,000 l/second, temperature from 6 to 15°C, pH from 6.2 to 7.8, conductivity from 128 to 570 mmoh/cm, total alkalinity from 20-220 meq/l, total hardness from 140-250 mg/l, oxygen from 7 to 11 mg/l, carbon dioxide from 5 to 20 mg/l (falling rapidly to less than 2 mg/l within a few tens of metres of the spring source), $H_2S$ 0 mg/l, $Cl^-$ 1-28 mg/l, $SO_4^{--}$ 14-135 mg/l, $PO_4^{--}$ 0.1-0.3 mg/l, $Ca^{++}$ 16-82 mg/l, $Mg^{++}$ 3-34 mg/l, $K^+$ 0.2-1.0 mg/l, $Na^+$ 0.5-1.5 mg/l, $Fe^{+++}$ 0-0.06 mg/l, $Fe^{++}$ 0 mg/l, $NO_2^-$ 0-0.2 mg/l, $NO_3^-$ 0-13 mg/l, $NH_4^+$ 0-0.5 mg/l, and $HCO_3^-$ 48-220 mg/l. Springs (or sarabs) in Kermanshah Province have been described by Khatami and Shayegan (2003) and are regarded as a significant water supply for rivers. Sarabs are used for drinking water and irrigation, and are threatened by pollution and fish farms. The Sarab-e Ravansar is the type locality for *Chondrostoma esmaeilii*. Qanats are also found, in drier parts of the basin, but they are not as significant for fish habitat as in other parts of Iran.

Lakes, marshes and ponds, as well as seasonally flooded arable land, in the upper reaches of the Iranian Tigris River basin and on the lowlands of Khuzestan provide temporary and permanent habitats for fishes. Some are reviewed below.

Lake Zaribar, Zarivar or Zeribar is a permanent freshwater body with fringing reed beds

and extensive marshes lying at 1,435 m in the Diyala River drainage just west of Marivan at 35°32'N, 46°08'E in Kordestan. The lake was designated as the Zarivar Wildlife Refuge in 2009 by the Department of the Environment and was proposed as a Ramsar Site by Zarei *et al*. (2017) based on the avifauna. The lake became a Ramsar Site in 2019. It has an area of 8 sq km and a maximum depth of 6 m and an average depth of 2.5-3.5 m (or minimum 6 m and maximum 12 m after Reyahi-Khoram and Hoshmand (2012)). Reputedly the lake is fed by 600-700 springs. At high water it overflows into a small river at its southern end. In winter it often freezes over. It was damaged in the Iran-Iraq War suffering rocket and missile hits and chemical warfare (Scott, 1995, 1997). Sharifinia *et al*. (2013) gave a water quality assessment for the lake finding it to be low or slightly polluted with an average water quality. Temperature range was 3.5-30°C, pH 7.28-8.33, dissolved oxygen 2.65-11.193 mg/l, $NH_3^{2+}$ 0.001-0.114 mg/l, $NH_4^+$ 0.11-11.33 mg/l, nitrite 0.001-0.011 mg/l, phosphate 0.04-0.68 mg/l, total phosphate 0.019-1.45 mg/l, conductivity 295.0-426.9 µS/cm, total dissolved solids 141.9-201.7 mg/l, total suspended solids 0.0645-0.1140 g/l, turbidity 0.763-3.987 NTU (Nephelometric Turbidity Units), alkalinity 89.0-121.3 mg/l, chemical oxygen demand 9.1-93.1 mg/l, biological oxygen demand ($BOD_5$) 3.2-12.8 mg/l, total organic carbon 3.97-14.73 mg/l and faecal coliform 0-1,278 MPN/100 ml (MPN = most probable number). Amini and Qishlaqi (2020) examined potentially toxic metals from bottom sediments and found that the lead, copper and zinc, with average contributions of 79, 64 and 54% respectively, were mainly derived from anthropogenic sources, whereas nickel and chromium, with estimated contributions of 80 and 89% were predominately from a lithogenic source. Lead was the contaminant of most concern. Domestic sewage, illegal water abstraction by wells and climate change all threaten the lake’s survival (*Tehran Times*, downloaded 31 December 2017). There is a small resort at the southeast corner of the lake, the surrounding land has livestock grazing and agriculture with drainage channels for the peripheral marshes, forests are cut for fuel, and there is waterfowl hunting and fishing. Javid. and Jalalian (2019) showed that human activities in nine villages around the lake had an unstable relationship with the lake ecosystem and significant amounts of pollution was entering the lake, leading ultimately to destruction of this ecosystem. Exotic fish species have been introduced by a government organization, and probably by accident, including *Alburnus alburnus* (= *A. hohenackeri*), *Ctenopharyngodon idella*, *Cyprinus carpio* (in two varieties), *Hemiculter leucisculus*, *Hypophthalmichthys molitrix*, *H. nobilis*, *Pseudorasbora parva*, *Gambusia holbrooki* (eastern mosquitofish) and even *Piaractus brachypomus*, a serrasalmid from South America, recorded by Zarei and Rajabi-Maham (2016). Native fish included *Barbus lacerta*, *Capoeta buhsei* (*sic*, not a Tigris River basin species), *Leuciscus cephalus* (= *Squalius berak*), and the spiny eel *Mastacembelus mastacembelus* (Scott, 1997). Jalali *et al*. (2002), Reyahi-Khoram and Hoshmand (2012) and Gholami and Shapoori (2017) added the species *Capoeta damascina* (*sic*, but Esmaeili *et al*. (2010) included C. *barroisi*, now recognised as *C. mandica*), *Carassius auratus* (given as *Carassius gibelio* by Esmaeili *et al*. (2010, 2011), and *Chalcalburnus* (= *Alburnus*) sp. Esmaeili *et al*. (2011) added *Squalius lepidus* from previous records but did not mention *Squalius cephalus* (= *S. berak*). Bahrami Kamangar *et al*. (2020) reported the northern pike (*Esox lucius*) as an invasive predator taking *Carassius carassius* (probably *C. auratus*), *Squalius cephalus* (= *S. berak*) and *Alburnus* sp. Jafari and Sobhanardakani (2014) and Sobhanardakani and Jafari (2014a) determined heavy metal (arsenic, cadmium, copper, lead, mercury and zinc) concentrations in *Ctenopharyngodon idella*, *Cyprinus carpio* and *Hypophthalmichthys molitrix* from the Zaribar Wetland, finding levels varying between species but all were lower than an adverse level for the fish and for human consumption. Solgi and

Khatoni (2015), however, evaluated cadmium, lead and zinc in *Cyprinus carpio* muscle tissue, finding that cadmium levels were higher than permissible.

This lake is the type locality for *Capoeta barroisi persica* (= *C. trutta*).

Kordestan, Zarivar Lake
(Aliafzali 1985 Zarivar Lake 5, CC BY-SA 3.0, Aliafzali 1985).

Abbasi *et al*. (2009) studied the wetlands in Hamadan Province encompassing part of the upper Tigris River basin and found 23 species in four families (Cyprinoidei (17), Nemacheilidae (4), Cobitidae (1) and Poeciliidae (1)). *Carassius auratus*, *Cyprinus carpio*, *Pseudorasbora parva* and *Gambusia holbrooki* (eastern mosquitofish) were exotics and the fauna was dominated by *Alburnus mossulensis* (= *A. sellal*) (28.0%), *Carassius auratus* (12.5%) and *Capoeta aculeata* (= *C. macrolepis*) (11.7%).

Lake Mirabad lies in the basin of the Karkheh River at 33°05'N, 47°43'E. While it measures only 100 by 200 m it is important for establishing past vegetation and environments based on sediment cores (Griffiths *et al*., 2001). The Hashelan or Hashilan Marsh or Wetland at 34°33'N, 46°55'E occupies 260 to 400 ha (accounts differ) northwest of Kermanshah at about 1,310 m. It is a complex of permanent spring-fed pools and associated marshes with much submerged, floating and emergent vegetation. The surrounding plains are heavily grazed and cultivated and ducks are hunted in the marshes. The Sabz Ali spring feeding the marsh has an average annual discharge of 323.4 l/sec, range 208.3-442.5 l/sec, highest in March and lowest in September. The total average volume of water in the marsh is estimated at 1.02 x $10^7$ cu m (Karami *et al*., 2001). Local people and those from Kermanshah fish in the marsh. A drought in 2008 severely affected the Hashilan Marsh (www.payvand.com/news/08/aug/1152.html, downloaded 5 July 2009). Mortazavi *et al*. (2016) found heavy metals in the wetland sediments at low to no risk for natural lead and iron while copper was anthropogenic and of low-moderate

risk. Norouzi and Rezaeimanesh (2021) found the marsh to be somewhat affected by contamination from human sources.

Kermanshah, Hashilan Marsh
(Hashilan Wetland 13951113 17, CC BY 4.0, Farzad Menati).

Gahar Lake in Lorestan at 33º18'2"N, 49°17'03"E, 35 km from Do Rud, lies at 2,400 m, is 1.7 km long and 600 m wide with a maximum depth of 28 m. It is principally fed by streams during periods of heavy flow and a few small springs on the lake bottom. The Gahar River exits the lake and eventually flows into the Dez River. Fish identified as *Capoeta damascina* (*sic*, possibly *C. pyragyi*), *Oncorhynchus mykiss* (rainbow trout) and *Salmo trutta* (*S. caspius*, Caspian trout, if from the Caspian Sea) are found in the lake and nine species of cyprinoids in the river (*Alburnoides bipunctatus* (*sic*, presumably *A. idignensis*), *Arabibarbus grypus*, *Capoeta damascina* (*sic*, possibly *C. pyragyi*), *C. trutta*, *Carasobarbus kosswigi*, *Chondrostoma regium*, *Cyprinion macrostomus*, *Garra rufa*, *Squalius cephalus* (= *S. berak*)) according to Ramin *et al*. (2014). Gorjian Arabi *et al*. (2013) used macroinvertebrate-based biotic indices to assess the water quality of this lake, finding it excellent and without apparent organic pollution. In contrast, Parishan Lake in Fars was fair with a medium possibility of organic pollution.

Lorestan, Gahar Lake,
(CC BY-SA 3.0, cropped, Meysam).

Lorestan, Gahar Lake in winter, 7 April 2004
(1388 Gohar Lake – Winter (in Farsi), CC BY 3.0, me_200416).

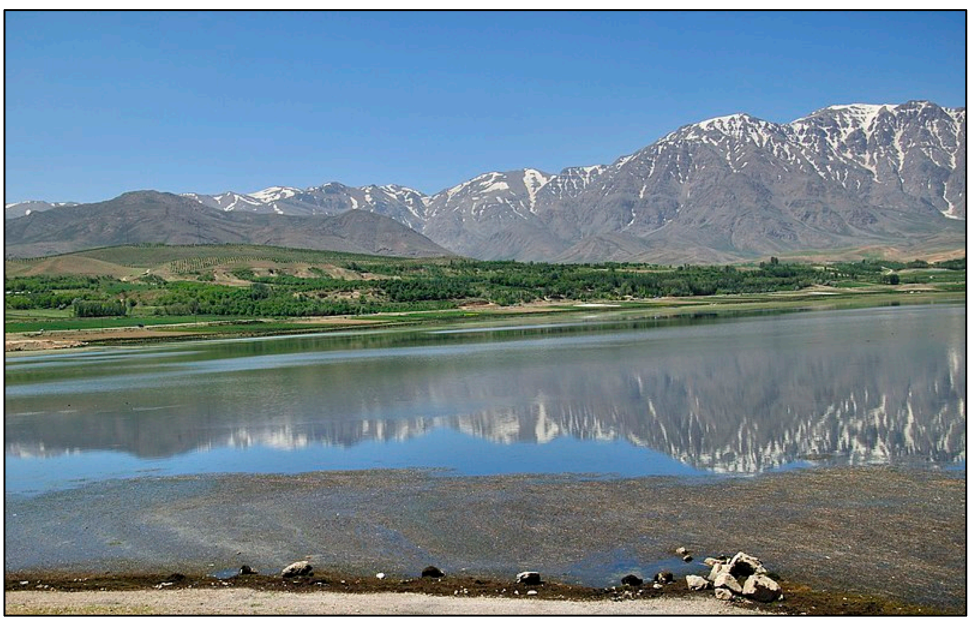
Golbolagh Lake or Reservoir in Kordestan was examined by Mohammadi (2016) and Mohammadi *et al*. (2017) and fish potential production and trophic status were estimated using chlorophyll a, phytoplankton phylum dominance and macrobenthos biomass. The lake was eutrophic to hypertrophic and the annual average of fish productivity was estimated at 138.42 kg/ha. Owing to the high trophic status of the lake, fish production was expected to be greater, but the low density of phytoplankton resulted in medium production. Chinese carps were the main fish species examined.

Izeh and Shiekho lakes at 31°52'N, 49°54'E occupy 1,400 ha in the Zagros foothills of Khuzestan east of Ahvaz. These small freshwater lakes are shallow with extensive sedge marshes. Izeh is the deeper of the two with much more open water. They are fed by runoff and springs. Shiekho, the larger lake, is almost overgrown with emergent vegetation except where cattle have grazed and trampled areas leaving some open water. Some fishing occurs in the lakes and water is abstracted for irrigation.

The Pol-e Dokhtar Wetlands in Lorestan have been described by Piroozi and Tavakoli (1996) and Mehdinasab (2019), for example, and consist of eight permanent and three seasonal wetlands, mostly mesotrophic and in danger of desiccation.

Chagha Khur, Chaghkhor, Choghakor, Chogakhor, Cheghakhor or Chaghakhour Lagoon, Lake, Marsh or Wetland at 31°55'N, 50°54'E lies in upper Karun River drainage in the Zagros Mountains in Chahar Mahall and Bakhtiari Province at ca. 2,100-2,270 m and occupies 1,360-1,687 ha (sources vary and the wetlands obviously vary in size with the seasons). Baqeri (2000) gave a general description and Asadolahi *et al*. (2012) discussed protective zoning of the wetland. Fathi *et al*. (2015, 2016) sampled the wetland over a year at 10 stations and assessed water quality as very poor or bad to inappropriate, not suitable for human use with the most important factor in assessing water quality being biochemical oxygen demand. Abolhasani *et al*. (2019) summarised the physicochemical parameters of the water and found that the nitrate level was the main restricting factor in management of the wetlands which were oligotrophic in spring and winter and mesotrophic in summer. Dehghannezhad *et al*. (2019) sampled 40 stations during summer and found the wetland to be mesotrophic.

A stream in the upper Karun River basin nearby is the type locality of *Alburnus zagrosensis* (= *A. sellal*).



Chahar Mahall and Bakhtiari, Chagha Khur Lake
(Chogakhor lake …., CC BY 3.0, Farid Atar).

Maximum depth in spring and winter is 2 m but in summer it is almost entirely dry and overgrown with emergent vegetation. Construction of a dam may enable a more permanent marsh to exist (Taqvaie and Ramezani, 2002) although others considered dam construction to be

a threat to the habitat and its diversity as the habitat changes from a wetland to a lake (Ebrahimi and Moshari, 2006). After the dam was built, water depth increased from 1.5 m to 6 m or more. Mousavi Nadoushan *et al*. (2008) recorded introduction of cyprinoids, which along with water level fluctuations and agricultural discharge, caused serious changes in trophic states. Fish yield potential was estimated at 34.4 kg/ha. Rahimi and Raeisi (2009) found lead and cadmium levels in fish tissues from this marsh exceeded tolerance limits established by the European Commission. These high concentrations probably came from misuse of phosphate fertilisers in local agriculture. Pirali Zefrehei *et al*. (2020) used Landsat imagery over 32 years (1985-2017) to monitor spatiotemporal variability of water quality and help detect long-term changes and move to optimal management and protection of this wetland. The western part of the wetland, as compared to other areas, was affected by these changes, which could be due to the human activity concentrated in this area.

Fadaei Fard *et al*. (2001) and Raissy *et al*. (2008) recorded *Alburnus alburnus* (*sic*, possibly *A. hohenackeri*), *Alburnus mossulensis* (= *A. sellal*), *Capoeta aculeata* (= *C. macrolepis*), *C. damascina* (*sic*, presumably *C. coadi*), *Carassius auratus*, *Chondrostoma orientale* (*sic*, probably *C. regium*), *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix* and the aphaniid *Esmaeilius vladykovi* from this marsh area. The parasites *Dactylogyrus anchoratus*, *D. extensus*, *D. lamellatus*, *D. lenkorani*, *D. spiralis*, *Gyrodactylus* sp. (1 and 2), *Diplostomum spathaceum*, *Tylodelphys clavata*, *Ornithodiplostomum* sp., *Kawia* sp., *Bothriocephalus gowkongensis*, *Allocreadium isoporum*, *Ichthyophthirius multifilis*, *Trichodina* sp., *Myxobolus* sp., *Lernaea* sp., *Rhabdocona* sp., *Acanthocephalorhynchoides cholodkowski* and a pseudophyllidean cestode were recorded from these fishes, with *Cyprinus carpio* having about 88% infestation. Raissy *et al*. (2011, 2013) reported on a parasitic outbreak of *Lernaea cyprinacea* in the Wetland.

Gandoman Marsh, Lagoon or Wetland at 31°50'N, 51°07'E at 2,250 m and occupying 1,500 ha (or 1,200 ha (Khan *et al*., 1992) or 3,510 ha (Taqvaie and Ramezani, 2002)) is a similar habitat but it has a stream running through it. Khoshkam *et al*. (2014) examined the use of this wetland in tourism and its associated problems. Foroughi Abari *et al*. (2015) studied drought and wet periods in this wetland over 19 years (1994-2012). Sulegan Wetland or Marsh in the same area encompasses 164 ha and is spring fed. These marshes have been proposed as a Ramsar Site although not yet formally designated (Scott and Smart, 1992). Raissy *et al*. (2010) recorded *Alburnus alburnus* (*sic*, possibly *A. hohenackeri*), *Capoeta aculeata* (= *C. macrolepis*), *C. damascina* (*sic*, presumably *C. coadi*), *Carassius auratus*, *Chondrostoma regium* and *Cyprinus carpio* from this lagoon, parasitised by *Ichthyophthirius multifilis*, *Trichodina* sp. (Ciliophora), *Myxobolus musayevi*, *Myxobolus* sp. (Myxozoa), *Dactylogyrus extensus*, *D. lenkorani* (Monogenea), *Diplostomum spathaceum*, *Tylodelphys clavata* (Digenea), and *Argulus foliaceus* and *Lernaea cyprinacea* (Crustacea), with 77.7% of fish infected with at least one of these. Cheraghali and Chamani (2020) found copper and lead concentrations in wetland sediment were lower than standards, but zinc was close to the standard and cadmium was higher, the latter attributed to the use of pesticides ad phosphate fertilisers in the surrounding farmland.

Chahar Mahall and Bakhtiari, Gandoman Marsh or Wetland
(CC0, NASA Earth Observatory).

Chahar Mahall and Bakhtiari, Gandoman Wetland, Hamid Reza Esmaeili.

The Hanna Wetland in Esfahan Province is eutrophic and has a mean water temperature, dissolved oxygen, nitrate and phosphate in spring of 14.79°C, 8.01, 1.18 and 0.05 mg/l, 20.65°C, 7.46, 2.26 and 1.2 mg/l in summer, 11.33°C, 7.94, 1.89 and 0.67 mg/l in the fall and 5.34°C, 9.73, 5.27 and 0.03 mg/l in winter respectively (Farhadian *et al*., 2014).

The Hawr-e Bamdej or Sadi Shavour Marshes fed by the Shavour River lie between the Karkheh and Dez rivers northwest of Ahvaz at 31°45'N, 48°36'E and encompassed 12,000 ha although drought shrunk this to 1,416 ha. This is the most extensive permanent freshwater marsh with tall reeds of *Phragmites* and *Typha* in Khuzestan. There is relatively little open water. Some parts are being drained for agriculture, a continuing trend for marshes with concomitant loss of fish habitat. Fish ponds will also affect the native fauna. Filling of the Shavour Dam in May-June also cut off the water supply. Gorgizade *et al*. (2014) evaluated the water quality, assessed as medium, and gave details and sources on the threats outlined above.

The Hamidieh plains at 31°20'N, 48°20'E comprise 20,000 ha of seasonally flooded (winter) plain and arable land along the Karkheh River. Hamidieh Lake, an old oxbow of the Karkheh, is included in this area and is permanent fresh water. The lake is 3 ha and has extensive reed beds.

As lowlands at the head of the Persian Gulf receive waters from the vast Tigris-Euphrates drainage basin, floods occur, increasing the depth and extent of marshes. Flood waters may increase depths by 1-1.5 m, with 2.0-3.5 m in more permanent basins. Most of the large marshes lie in Iraq, but the Hoveyzeh or Hawr al Azim marshes are on the border, and occupy 3,000 sq km at high water. They are fed by the Karkheh and other rivers from Iran. Construction of the Karkheh Dam in Iran (and pipeline water transfer to Kuwait) will reduce input of water to this marsh, compounded by canal construction and draining of marshes in Iraq (Marjanizadeh *et al*., 2009). Additionally, irrigation return waters will be salinised (Partow, 2001). A description of the ecological characteristics of the Hawr al Azim marshes was given by Dehghan Madiseh *et al*. (2018). It was noted that 87.4 percent of all identified fish species in the wetland belonged to the Cyprinidae family (cyprinoids), notably karas

(*Carassius auratus*) and hemry (himri, *Carasobarbus luteus*) but also including *Alburnoides bipunctatus* (presumaby *A. idignensis*, listed as such by Esmaeili (2021)), *Aspius* (= *Leuciscus*) *vorax*, *Capoeta trutta*, *Cyprinion kais*, *C. macrostomus*, *Cyprinus carpio*, *Luciobarbus barbulus*, *L. pectoralis* (*sic*, probably *L. barbulus* according to Esmaeili (2021) base on COI gene sequences), *L. xanthopterus*, *Mesopotamichthys sharpeyi* and *Tor* (= *Arabibarbus*) *grypus*. Esmaeili (2021) also listed the fishes in this marsh and added *Garra rufa*, *Luciobarbus esocinus*, *L. kersin*, *Acanthobrama marmid*, *Alburnus sellal* and *Chondrostoma regium*. *Carasobarbus sublimus* was also listed but is more likely to be in the Shadegan Marsh, treated in the same paper. Permanent marshes in the Hawr al Azim have declined by 47.5% from 1973-1976 to 2000, permanent lakes by 33.0% and seasonal/shallow lakes by 2.0%, before the Karkheh Dam came online (Marjanizadeh *et al*., 2009). Dust storms are now a feature of this area (Adib *et al*., 2018). A dam has been built by Iran across the Hoveyzeh marsh to retain water on the border with Iraq. Marsh temperatures range from 15°C in January to 31°C in August and fish may retreat to deeper areas or move upriver at the higher temperatures. Flooded marshes tend to be warmer than rivers in winter. Rezaei and Papahn (2003) and Papahn *et al*. (2013) sampled the Hoveyzeh Marsh using gill nets at three stations and found 15 species with *Carasobarbus luteus* at 28.7%, *Mesopotamichthys sharpeyi* at 24.6%, *Aspius* (= *Leuciscus*) *vorax* at 15.7%, *Liza* (= *Planiliza*) *abu* (abu mullet) at 10.8%, *Carassius auratus* at 9.9%, *Cyprinus carpio* at 5.4% and *Silurus triostegus* (Mesopotamian catfish) at 1.8%. Up to 11 species were captured at one sampling station. The average water temperature was 20.72°C, salinity was 2.07‰ and pH was 7.28. In contrast, Asadi *et al*. (2011), using gill nets at three stations in this marsh, found 19 fish species with *Liza* (= *Planiliza*) *abu* (abu mullet) at 23.95%, *Aspius* (= *Leuciscus*) *vorax* at 15.03%, *Carasobarbus luteus* at 10.41%, *Carassius auratus* at 8.14% and *Silurus triostegus* at 6.4%. The average water temperature of the marsh was 21.1°C, salinity was 1.79‰ and pH was 7.5.

Fatemi and Hamidi (2010) determined levels of the heavy metals cadmium and lead in fish from the Hawr al Azim, in muscle tissue of *Aspius vorax* (= *Leuciscus vorax*), *Barbus grypus* (= *Arabibarbus grypus*), *Barbus luteus* (= *Carasobarbus luteus*), *Barbus sharpeyi* (= *Mesopotamichthys sharpeyi*) and *Barbus xanthopterus* (= *Luciobarbus xanthopterus*). Maximum levels of lead were detected in *Leuciscus vorax* at the Shat-Ali station (1.62 p.p.m.) and minimum levels were detected in *Arabibarbus grypus* at the Rofae' station (0.5 p.p.m.). For cadmium, maximum and minimum concentrations accumulated in *Luciobarbus xanthopterus* and *Carasobarbus luteus* at the Shat-Ali station (0.09 p.p.m.) and *Arabibarbus grypus* at the Shat-Ali station (0.02 p.p.m.), respectively. Based on the results, some fish species in the wetland had high concentrations of lead and cadmium and, therefore, consumption of these species may have a potential risk for human health and should be approached with consideration. Velayatzadeh *et al*. (2014) assessed protein, lipid, carbohydrate, ash, moisture and zinc and iron in three species of fish, *Aspius vorax*, *Barbus pectoralis* (probably *Luciobarbus barbulus*) and *Carasobarbus luteus*, in the marsh. Protein, ash and carbohydrate showed no significant differences between the species while lipid and moisture did. The highest levels of protein, lipid and carbohydrate were in the muscle of *Barbus pectoralis* and the highest ash level and moisture in *Carasobarbus luteus*. The lowest protein and lipid levels were in *Carasobarbus luteus* and the lowest ash and moisture in *Barbus pectoralis*. The concentration of iron in muscle of *Barbus pectoralis*, *Carasobarbus luteus* and *Aspius vorax* was 10.96, 10.46 and 9.73 mg/kg wet weight. The concentration of zinc in muscle of *Barbus pectoralis*, *Carasobarbus luteus* and *Aspius vorax* was 11.9, 12.9 and 10.93 mg/kg we weight. Payandeh and Velayatzadeh (2019) measured

heavy metal concentrations in sediments of this marsh, finding selenium was the most important contaminant, chromium, manganese, molybdenum and selenium were of human origin, and chromium, cobalt and molybdenum were of low ecological risk.

Khuzestan, Hawr al Azim
(Hoorolazim Wetlands 20170704 05, CC BY 4.0, cropped, lightened, Medi Pedramkhoo).

Khuzestan, Hawr al Azim
(Hoorolazim Wetlands 20190417 20, CC BY 4.0, cropped, J. Zobeidi).

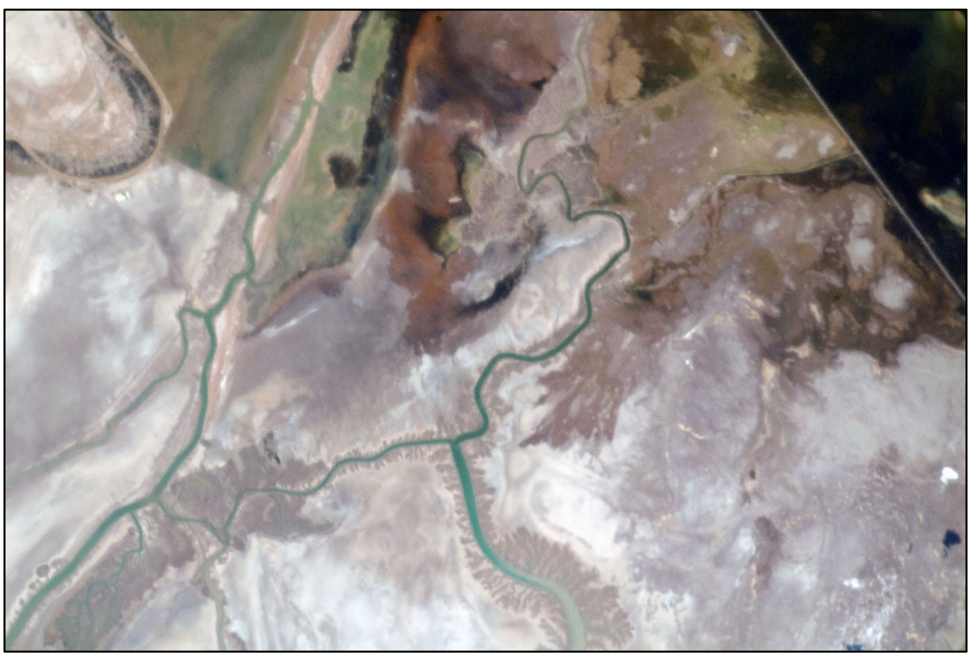
Khuzestan, Hawr al Azim
(1398122414390088419912094 …., in Farsi, CC BY 4.0, Milad Hamadi).

Some loss of fish stocks must occur as floods recede from these southern marshes and rivers. For example, the Jarrahi and Zohreh rivers overran their banks in November 1994 after torrential rains causing widespread flooding (http://netiran.com/news/IranNews/html/94112109INEV.html).

The Susangerd Marshes or Hawr-e Susangerd at 31°45'N, 47°55'E are northwest of Ahvaz near the Iraqi border and form the extreme eastern edge of the Hawr al Azim, most of which lies in Iraq. The marshes occupy about 30,000 ha and are made up of permanent and seasonal fresh and brackish marshes and seasonally flooded arable land. The marshes are on the floodplain of the Karkheh River. Irrigation projects, grazing by livestock, reed cutting and fishing all occur here. Parts of the marsh were damaged by the Iran-Iraq War. The Iran-Iraq marshes declined in area from 1,089 sq km to 758 sq km from 2000 to 2002 and were predicted to dry up in five years from 2002 because of the Karkheh Dam. Reports conflicted since once the dam was full, a relatively normal flow regime would help maintain the marshes.

The Shadegan Marsh or Wetland at 30°20'N, 48°20'E occupies 282,500 ha (Jones, www.ramsar.org/lib_dir_2_3.htm, downloaded 4 April 2000 gave 296,000 ha, Hashemi *et al*. (2012) 400,000 ha, the largest wetland in Iran) and form the southern part of the seasonal floodplain of the Jarrahi River and other rivers at the head of the Persian Gulf. The major part of the water feeding the marsh is now from irrigation return flows, including water from fish farms and the sugarcane industry. The area is sometimes referred to as the Shadegan Ponds or Shadegan Lagoon, presumably referring to open waters in the wetland. There are adjacent tidal mudflats at the head of the Persian Gulf. The central and southern parts of the marshes are part of a Ramsar Site, along with the mudflats of Musa Bay (World Conservation Monitoring Centre, 1990; Kaffashi *et al*., 2012). Mirzaei *et al*. (2019) found that the stability of the wetland was weak and improvement was needed in water supply, in laws and in means of coping with natural disasters such as drought. Mohamadi *et al*. (2019) studied rehabilitation of the wetland with regard to the sugarcane industry drainage, aquaculture and dust control. Esmaeili (2012) listed the fishes here and in the Hawr al Azim.

Khuzestan, Shadegan Marshes
(CC0, NASA).



Khuzesan, Shadegan Marsh, Khowr-e Guban
(CC0, tone and contrast adjusted, NASA).

Khuzestan, Shadegan Marsh at Rogbeh, CMNFI 2008-0166, 25 November 2000,
no cyprinoids, only the mugilid *Planiliza abu*
(marsh mostly dry, flooded in November 1999), Brian W. Coad.

Khuzestan, Shadegan Marsh
(Shadegan International Wetlands, CC BY-SA 4.0, cropped,
Ehsan Doostmohammadi).

Khuzestan, Shadegan Marsh
(Talabe shadegan - panoramio, CC BY 3.0, internet alghadir sh).

Sabzalizadeh and Amirineia (2003) gave some physical and chemical characteristics of five sample stations in Shadegan Marsh. Range of pH was 7.2-9.4 and maximum water temperatures occurred in July and August. Maximum levels of dissolved oxygen were found in November and February but were more than 5 p.p.m in most cases, optimal for fish growth and reproduction. The water quality was hard and brackish. The whole area may dry out in late summer, a natural condition exacerbated by dams and irrigation schemes on the major inflowing rivers. Hormozi *et al*. (2019) reported that all rainfall-related indices had a decreasing trend in Khuzestan related to climate change and this was having significant effects on the Shadegan Wetland. Jafari *et al*. (2019) described many changes in drought and wet conditions from 1950 to 2015 using data from the Meteorological Agency, water and power authorities and NOAA satellites. In a November 2000 visit by me, much of this area was dry although it had been flooded in 1999. When the marsh dries, fish concentrate in the deeper pools where they are easily caught, even the smaller ones. The marsh is re-colonised from the rivers. Saline intrusions occur when freshwater input from rivers is low. Lotfi (2018c) cited an average annual temperature of the wetland area as 25ºC with a maximum of 51ºC and minimum of 1.4ºC. Average annual precipitation in the catchment area varies between 200 mm in the wetland area in the south to about 800 mm in the northern higher altitudes of the catchment. Water depth is up to 3 m but the average is less than 1 m. Nouri *et al*. (2010) compared water quality in dry and wet years, finding high phosphate concentrations resulting in mesotrophic conditions in the former and high concentrations of nitrate and silicate resulting in oligo-mesotrophic conditions in the latter. Causes were climatic patterns, water residence time, reduced runoff, and increasing wastewater density from urban, industrial and agricultural areas. A descending trend in high-value endemic fish species was noted with a concomitant increase in more tolerant species. Sima and Tajrishy (2006) modelled water allocation between the wetland and irrigated agriculture and predicted a 100% failure in

the wetland and suggested conserving some parts to reduce this failure. Ghorbani *et al*. (2016) used chlorophyll-a to assess the trophic state index of the Shadegan Wetland which was found to be mesotrophic in the spring and winter and eutrophic in the summer and fall. Overall, the lake was suitable for warmwater species.

Esmaeili (2021) listed the cyprinoids from the Shadegan Marsh as *Arabibarbus grypus*, *Carasobarbus luteus*, *Carassius auratus*, *Cyprinion kais*, *C. macrostomus*, *Cyprinus carpio*, *Luciobarbus barbulus*, *L. kersin*, *L. xanthopteru*s, *Acanthobrama marmid*, *Alburnoides idignensis*, *Alburnus sellal*, *Chondrostoma regium* and *Leuciscus vorax*. Fishing is important. The fishes of this marsh in order of abundance are kopur (*Cyprinus carpio*), shirbot (*Arabibarbus grypus*), touyeni (*Capoeta* sp., possibly *C. pyragyi*), esbele (*Silurus triostegus*, Mesopotamian catfish), binni (*Mesopotamichthys sharpeyi*), berzem (possibly *Luciobarbus barbulus* or *L. kersin*), biah (a mugilid, probably *Planiliza abu*) and very few himri (*Carasobarbus luteus*) and gattan (*Luciobarbus xanthopterus*) (Y. Mayahi, pers. comm., 2000). Hashemi *et al*. (2011) found a maximum fish biomass of 249.61 kg/ha/yr in spring and a minimum of 157.9 kg/ha/yr in winter in this wetland while other studies gave 337.17 kg/ha/yr in autumn and 83.19 kg/ha/yr in summer (Hashemi *et al*., 2010a, 2010b) and 380.4 kg/ha for spring, 71.0 kg/ha for summer and 58.41 kg/ha/yr for winter (Hashemi *et al*., 2012; Hashemi and Ansary, 2012). An estimated 2,000 t can be harvested from a biomass of about 11,000 t although over-exploitation was evident at about 3,738 t. A comparison with an earlier 1997 study showed that the biomass of *Arabibarbus grypus*, *Carasobarbus luteus*, *Carassius carassius* (probably *C. auratus*), *Mesopotamichthys sharpeyi*, *Liza* (= *Planiliza*) *abu* (abu mullet) and *Silurus triostegus* (Mesopotamian catfish) increased while *Aspius* (= *Leuciscus*) *vorax*, *Cyprinus carpio* and *Luciobarbus pectoralis* (probably *L. barbulus*) decreased with changes in environmental conditions. Variations in fish biomass were attributed to loss of floodplain areas, dam construction altering the hydrological regime, increased salinity from irrigation, and pollution. The three most productive cyprinoids were *Carasobarbus luteus* at 40.1 kg/ha/yr, *Mesopotamichthys sharpeyi* at 25.93 kg/ha/yr and *Carassius carassius* (probably *C. auratus*) at 17.67 kg/ha/yr (Hashemi and Ansary, 2012). Hashemi and Eskandary (2013) for a 2008-2009 study found the maximum fish biomass was shown by *Cyprinus carpio*. Hashemi *et al*. (2014) estimated fish composition and the catchability coefficient of gill nets in Shadegan. For cyprinoids the coefficient was maximum for *Carasobarbus luteus* and minimum for *Cyprinion macrostomus*, *C. kais* and *Luciobarbus barbulus*. The most numerous species caught among cyprinoids were in descending order *Cyprinus carpio* (836 fish), *Carassius auratus* (455), *Mesopotamichthys sharpeyi* (417), *Aspius* (= *Leuciscus*) *vorax* (193) and *Carasobarbus luteus* (104) with no other species exceeding 50 specimens, and the species with minimum coefficients being represented by single specimens. Hashemi *et al*. (2015) gave different numbers:- *Carasobarbus luteus* (934, 28.2%), *Cyprinus carpio* (613, 18.5%), *Carassius carassius* (probably *C. auratus*, 437, 13.2%), *Mesopotamichthys sharpeyi* (336, 10.1%) and *Aspius* (= *Leuciscus*) *vorax* (191, 5.8%), with no others above 75 fish. However, they noted that of these fish *C. carpio* and *M. sharpeyi* (along with *Hypophthalmichthys molitrix*, *H. nobilis*, *Ctenopharyngodon idella* and *Arabibarbus grypus*) were stocked from 2009 to 2012 and cyprinoid abundance increased.

Ansari (2016) estimated biomass of fishes by the depletion method in 2011-12 in the Shadegan Wetland. Fishing effort and landing catch amount per unit effort was done monthly via random oversight in fixed landing areas. Fishermen and catch statistics were obtained by census. The total catch was calculated from multiplication of effort and average catch. A biological

characteristics survey indicated that golden barb *Barbus* (= *Carasobarbus*) *luteus*) and berzem (*Barbus pectoralis* (= probably *Luciobarbus barbulus*) had a maximum (62 kg/ha) and minimum (4 kg/ha) biomass, respectively. Maximum and minimum biomass was in spring (380 kg/ha) and in winter (58 kg/ha) respectively and mean biomass was estimated at 249 kg/ha in the whole area during one year. The number of fishermen was about 1,317 and maximum fishing effort was in April, May and June. Total fish landings were 4,300 tons per year in which 1,119 t was in April. The range length of most fishes was low and their spawning season was in winter and spring. Length-weight relationships indicated isometric growth. Despite a 45% decrease in the number of fishermen since 2008, the catch effort and exploitation increased (20%). In regard of the fish living area (70,000 ha), the total biomass was 17,430 t.

Hashemi (2016) described the Shadegan ecosystem based on five stations and the biodiversity of fish based on 3,312 fish of 27 species and seven families caught monthly from April 2013 to March 2014. Data also appeared in other articles by this author and colleagues and the below is a summary. Threats to the wetland included upstream allocation of water resources for agriculture, industry and residential uses, increased drainage flow from aquaculture, pollution from agriculture, industry, hospitals and domestic sources (including pesticides used for fishing), reduced flows from flooding control and climate change, introduction of exotic species from aquaculture, development of farm land, buildings, roads, power plants and other industry, canal and drainage construction, degradation of water quality from fish poisons, logging waste and rural wastewater, and excessive harvesting of wildlife. Sixteen species caught were cyprinoids (see Hashemi *et al*. (2014, 2015) above for the main species, of which data on only six are given below as the remaining cyprinoids are represented by few specimens, 13 or less per species). The highest fish biomass was in spring and the lowest in winter and it varied between stations. Fish biomass was strongly correlated with temperature (fish biomass = $43.73 + 1.73^{\text{temperature}}$). Overall, nearly 90% of production was from *Carasobarbus luteus*, *Carassius carassius* (probably *C. auratus*), *Mesopotamichthys sharpeyi* and *Silurus triostegus* (Mesopotamian catfish). Length-weight relationships from the text and Table 2 were $Y = 0.0001TL^{2.56}$ (*Mesopotamichthys sharpeyi*), $Y = 0.0001TL^{2.59}$ (*Carasobarbus luteus*, although *b* = 2.6 in Table 2), $Y = 0.00004TL^{2.8}$ (*Carassius carassius*, probably *C. auratus*), $Y = 0.0009TL^{2.22}$ (*Cyprinus carpio*) and $Y = 0.0002TL^{2.88}$ (*Aspius* (= *Leuciscus*) *vorax*). Other values for Shadegan by Hashemi (2010, presumably references 2010a and 2010b herein) cited in this 2016 work were $Y = 0.0055TL^{3.24}$, $Y = 0.0116TL^{3.06}$, $Y = 0.0099TL^{3.16}$, $Y = 0.0132TL^{3.04}$ and $Y = 0.014TL^{2.85}$ respectively. Fulton's condition factor (K) from Table 3 was 1.48, 1.42, 1.62, 1.5 and 0.91 for these species. Population dynamic parameters were as follows for *Mesopotamichthys sharpeyi*, *Carasobarbus luteus*, *Carassius carassius* (probably *C. auratus*), *Cyprinus carpio* and *Aspius* (= *Leuciscus vorax*) respectively:- $L_\infty$ = 393, 304, 346, 537 and 498 mm, K = 0.29, 0.55, 0.36, 0.36 and 0.45 $yr^{-1}$, $t_0$ = -0.53, -0.29, -0.23, -0.2 and -0.16, Φ' = 2.65, 2.7, 2.63, 3.01 and 3.04, natural mortality (M) = 0.62, 1.02, 0.75, 0.66 and 0.78, fishing mortality (F) = 0.74, 1.6, 0.77, 0.78 and 0.68, total mortality (Z) = 1.36, 2.62, 1.52, 1.44 and 1.46, exploitation rate E = 0.54, 0.61, 0.51, 0.54 and 0.47, relative yield per recruitment (Y'/R) = 0.01, 0.03, 0.02, 0.02 and 0.03, relative biomass per recruitment (B'/R) = 0.4, 0.3, 0.3, 0.3 and 0.3, and exploitation ratio maximum sustainable yield ($E_{max}$) = 0.49, 0.65, 0.58, 0.68 and 0.43. The species, except *C. luteus*, were overfished. Average physicochemical parameters by seasons did not vary markedly between stations (and see below) except for salinity. Hashemi *et al*. (2016) related physicochemical factors with fish biomass and production which varied seasonally. Temperature, salinity, pH and dissolved oxygen were the most important variables affecting fish composition, with these

variables except pH and with the addition of depth, having the greatest impact on biomass.

Valikhani *et al*. (2018) found the exotic cichlid *Coptodon zillii* (redbelly tilapia) was a dominant species in Shadegan with a relative abundance of almost 50% in autumn. Relative abundance values for *Coptodon zillii* were 23.64%, 33.49% and 49.83% for summer, spring and autumn respectively, for the exotic cichlid *Oreochromis aureus* (blue tilapia) 3.81, 4.64 and 5.24%, for the clupeid *Tenualosa ilisha* (Indian shad) 0, 4.91 and 0%, for the mugilid *Liza* (= *Planiliza*) *abu* (abu mullet) 15.89, 0 and 20.99%, for the sparid *Acanthopagrus latus* (*sic*, presumably *A. arabicus*) (Arabian yellowfin seabream) 0, 0.22 and 0%, for the exotic xenocypridid *Ctenopharyngodon idella* (grass carp) 0.8, 0 and 0%, for the exotic xenocypridid *Hemiculter leucisculus* (sharpbelly) 1.9, 0 and 0%, for the leuciscid *Leuciscus vorax* 2.6, 0.56 and 2.27%, for the exotic *Carassius auratus* 3.81, 10.27 and 12.24%, for the exotic *Cyprinus carpio* 4.19, 0 and 0%, for *Arabibarbus grypus* 0.19, 1.12 and 0.17%, for *Carasobarbus luteus* 23.52, 28.12 and 1.57%, for *Luciobarbus barbulus* 10.29, 2.9 and 4.72%, for *Luciobarbus xanthopterus* 5.08, 0 and 0%, and for *Mesopotamichthys sharpeyi* 4.38, 13.95 and 2.97%. Fishes observed at Sarrakhieh village fish market by relative abundance in summer, spring, winter and autumn were for *Coptodon zillii* 51.73, 62.77, 40.48 and 69.36%, dominating the market at all seasons, for *Planiliza abu* 20.97, 0, 0 and 0%, for *Leuciscus vorax* 1.1, 3.1,1.73 and 0%, for *Carassius auratus* 3.86, 1.03, 4.84 and 0%, for *Cyprinus carpio* 0, 2.07, 2.08 and 0%, for *Arabibarbus grypus* 0.27, 0.69, 0.35 and 0%, for *Carasobarbus luteus* 14.62, 24.14, 42.22 and 29.35%, for *Luciobarbus barbulus* 3.31, 1.72, 0.69 and 0%, and for *Mesopotamichthys sharpeyi* 4.14, 4.48, 7.61 and 1.29%. Valikhani *et al*. (2020) combined fish from the Shadegan Wetland and the Dez and Karkheh rivers and found the condition factor was higher than one in 11 native species (nine cyprinoids) and the ecosystems were favourable for fish at the sampling time, June 2015.

Rice paddies occupy part of the Shadegan Marsh Ramsar Site with associated agricultural pesticides. Other potential pollution comes from main roads, shipping and oil terminals. Over 100,000 ha were contaminated with oil from a leaking pipeline in 2000 and 35,000 cu m of refinery wastes were dumped in the marsh in 2004 (www.payvand.com, downloaded, 5 September 2006). Esmaeili Sari *et al*. (2001) detailed the damages resulting from the Iran-Iraq War's oil pollution when 20% of the emergent vegetation was destroyed. Chemical weapon use occurred here in the Iran-Iraq War and acid rain fell from the burning of the Kuwaiti oilfields in the Gulf War. About 10% of the marshes were destroyed (Anonymous, 1988a; Scott, 1993; Jones, www.ramsar.org/lib_dir_2_3.htm, downloaded 4 April 2000). The Shadegan Wildlife Refuge, encompassing 296,000 ha, is on the threatened list for National Parks since it was substantially damaged in the Iran-Iraq War, both physically and by chemical agents. Mahmoudi Rad (2011) presented an integrated management plan and Kaffashi *et al*. (2012) studied economic valuation and conservation of the Shadegan International Wetland.

Davodi *et al*. (2010, 2011) examined edible fishes from the Shadegan Marshes for polychlorinated biphenyls and organochlorine pesticides. Levels were relatively low but some exceeded guidelines for food safety issued by the European Union and the U.S. Food and Drug Administration. Hosseini Alhashemi *et al*. (2012, 2012) reported on accumulation of cadmium, chromium, cobalt, copper, lead, manganese, nickel, vanadium and zinc in *Arabibarbus grypus*, *Carasobarbus luteus*, *Cyprinus carpio* and *Mesopotamichthys sharpeyi* in Shadegan. They found variations in levels between metals, species, body organs, gender, levels in sediment, condition factor and gonadosomatic index. The potential uptake of toxic elements in muscle decreased as *A. grypus*>*C. carpio*>*M. sharpeyi*>*C. luteus*, although *Liza* (= *Planiliza*) *abu* (abu mullet) had

the highest concentrations. Karimi *et al*. (2012) assessed the impact of the pesticides and herbicides aldrin, ametryn, DDT, dieldrin and lindane on the aquatic community of Shadegan Marsh. Risk quotients for *Arabibarbus grypus*, *Carasobarbus luteus*, *Mesopotamichthys sharpeyi* and chironomid larvae were high and the wetland was deemed vulnerable. Raeisi Sarasiab *et al*. (2014) found mercury and methyl mercury levels in *Barbus* (= *Arabibarbus*) *grypus* and *Barbus* (= *Luciobarbus*) *esocinus* in the Musa Bay or Estuary at the head of the Persian Gulf were as liver>gill>muscle>sediment but levels in the muscle tissue were below dangerous levels according to international standards. Heidari Chaharlang *et al*. (2019) mapped the heavy metals copper, iron and zinc in surface sediments of the Shadegan Wildlife Refuge by sampling 160 stations. Average concentrations were found with highest bioavailability of zinc in the northern, southern and western parts and accumulation of copper more in the western part and iron in the central and northern parts. Almasi *et al*. (2020) found that levels of atrazine in Shadegan waters were more than the standard allowable and indicated a risk for adults and children from drinking water exposure, but none for fish dietary exposure. Rahmanikhah *et al*. (2020) determined mercury levels in *Cyprinus carpio* and *Mesopotamichthys sharpeyi* from Shadegan were acceptable according to the international safety guidelines although local people should be warned about consumption of redbelly tilapia (*Tilapia* (= *Coptodon*) *zillii*).

Khuzestan, Musa Bay
(Musa Bay, Iran ESA372739, CC BY-SA 3.0 IGO, European Space Agency).

The principal fishes appearing on fish stalls in Ahvaz from marshes such as Shadegan are *Cyprinus carpio*, *Luciobarbus xanthopterus*, *Mesopotamichthys sharpeyi* and *Liza* (= *Planiliza*) *abu* (abu mullet), and cultured *Hypophthalmichthys molitrix* as escapees or plantings. Farm

ponds in Khuzestan have *Ctenopharyngodon idella*, *Cyprinus carpio, Hypophthalmichthys molitrix* and *Luciobarbus barbulus*. Hawr al Azim, Hawr al Hoveyzeh and the Shadegan These marshes are important refuges for fishes in Khuzestan (Korki, 1992; N. Najafpour, pers. comm., 1995). 490,000 fingerlings of *Barbus* (= *Mesopotamichthys*) *sharpeyi* and *Barbus* (= *Luciobarbus*) *xanthopterus* were stocked in this marsh in 2005, a 40% increase over the previous year (www.iranfisheries.net, downloaded 30 November 2005).

Various studies on fish parasites have been carried out in southwest Iran (Khuzestan Province) and these are mostly dealt with under the Species Accounts. Mortezaei *et al*. (2008), for example, collected fishes from the Hawr al Azim, Shadegan Marsh and Karun River and recorded such nematodes as *Rhabdocona denudata*, *R. fortunatowi, Rhabdocona* sp., Proleptinae, *Cucullanus* sp., *Pseudocapillaria tomentosa*, *Philometra karunensis, Philometra* sp., *Anisakis* sp. and *Contracaecum* sp. from 10 fish species. Legionnaires' disease (due to *Legionella pneumophila*) causes pneumonia in humans and was recorded from Khuzestan fish ponds by Moosavian and Dashti (2011).

Construction of fish farms is widespread throughout the Tigris River basin in Iran with rainbow trout (*Oncorhynchus mykiss*) in cold waters at elevation and various carps in warmwater, lowland areas.

*Oncorhynchus mykiss*, Lorestan fish farm, north of Aleshtar (golden form), 3 December 2000, Brian W. Coad.

For example, in Lorestan Province, 772 tonnes were produced by the Lorestan Province Fishery Company in 1997, 50 fish farms were under construction, and 125 pools built for aquaculture uses. The long-term aim was to increase fish production to 20,000 tonnes worth 156 billion rials and employing 10,000 people (*Tehran Times*, 22 September 1998). The Indian carps *Catla catla*, *C. cirrhosus*, *Cirrhinus mrigala* and *Labeo rohita* and were reared in aquaculture stations in Khuzestan (and Gilan on the Caspian Sea), are potential escapees into the natural environment, and are demonstrated disease carriers in Iran (Rezvani Gilkolaei, 2007; Haghighi-Khiabanian Asl, 2008; Hamidinejad *et al*., 2014; Hoseinzadeh Sahafi, 2011, 2014; Hosseinzadeh Sahafi *et al*., 2014, 2020; Hosseinzadeh Sehafi *et al*., 2014; Mortazavizadeh *et al*., 2014; Salehi, 2016; Eagderi *et al*., 2019; Beytsayah *et al*., 2021). Mohammadsalehi *et al*. (2014) studied rearing of the four Chinese carp species with ducks, finding production was 5,085 kg/ha in control ponds and 5,385 kg/ha with ducks. Farajifard *et al*. (2015) reviewed the indices of energy and economy in one- and two-harvests per year methods in fish farming in Khuzestan finding the highest and lowest efficiency rates in 40-acre, two-harvest methods in Ahvaz and 10-acre, two-harvest methods in Shushtar. Askary Sary and Karimi Sary (2014a) and Karimi Sari and Askary Sary (2014) determined iron concentrations in farmed fish in Khuzestan, namely *Ctenopharyngodon*

*idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *H. nobilis*. *H. nobilis* had the highest concentration in muscle tissue at 18.16 mg/kg dry weight. Hazard quotients were all less than one, indicating no risk in terms of human consumption.

Various rivers have had recorded instances of pollution with a few examples as follows. Nümann (1966) noted pollution in the Seymarreh-Karasu-Gamasiab rivers from an oil refinery and sugar factory which decreased fish populations, a condition exacerbated through the use of explosives, insecticides and herbicides by local people to catch fish. He also listed explosive usage on the rivers Khairabad (= Kheyrabad) and Zohreh.

A truck carrying diethyl hexanoyl plunged into the Kashkan River, a Karkheh tributary in Lorestan, 15 km from Pol-e Dokhtar resulting in the poisoning of thousands of fish on 13 April 1998 (*Islamic Republic News Agency*, 14 April 1998; *Brief on Iran*, 880, 16 April 1998). The river suffered an oil slick in October 2001 when the Khuzestan-Tehran pipeline fractured 4 km from Pol-e Dokhtar. Shahriari Nia *et al*. (2016) described the environmental flow of this river.

Lorestan, Kashkan River at Pol-e Dokhtar
(Poldokhtar, CC BY-SA 3.0, Poldokhtar1392).

Oil pollution caused a fish kill numbering about 70,000 fish in the Kambel River near Gachsaran, a centre of oil production (*Tehran Times*, 24 November 2002). Varkouhi and Sobhani (2005) and Varkouhi (2007) studied the presence of various pollutants in the livers of fishes in the Khorramabad River. Mortazavi *et al*. (2016) determined heavy metal concentrations of cadmium, lead and mercury in fish marketed at Khorramabad, including marine species from the Persian Gulf, and some freshwater ones presumably from rivers near Khorramabad (*Luciobarbus esocinus*, for example, possibly *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *H. nobilis* but not the Caspian Sea species *Rutilis frisii* (= *R. kutum*) presumably shipped south). All concentrations were lower than the maximum allowable levels. The Meymeh River in Ilam had some pollution from urban and rural sewage, and this may potentially increase (Cheraghi *et al*., 2007). The Meymeh River is the type locality for *Garra meymehensis*.

Lorestan, Khorramabad River at Shapouri Bridge (CC BY-SA 3.0, Farnaz25).

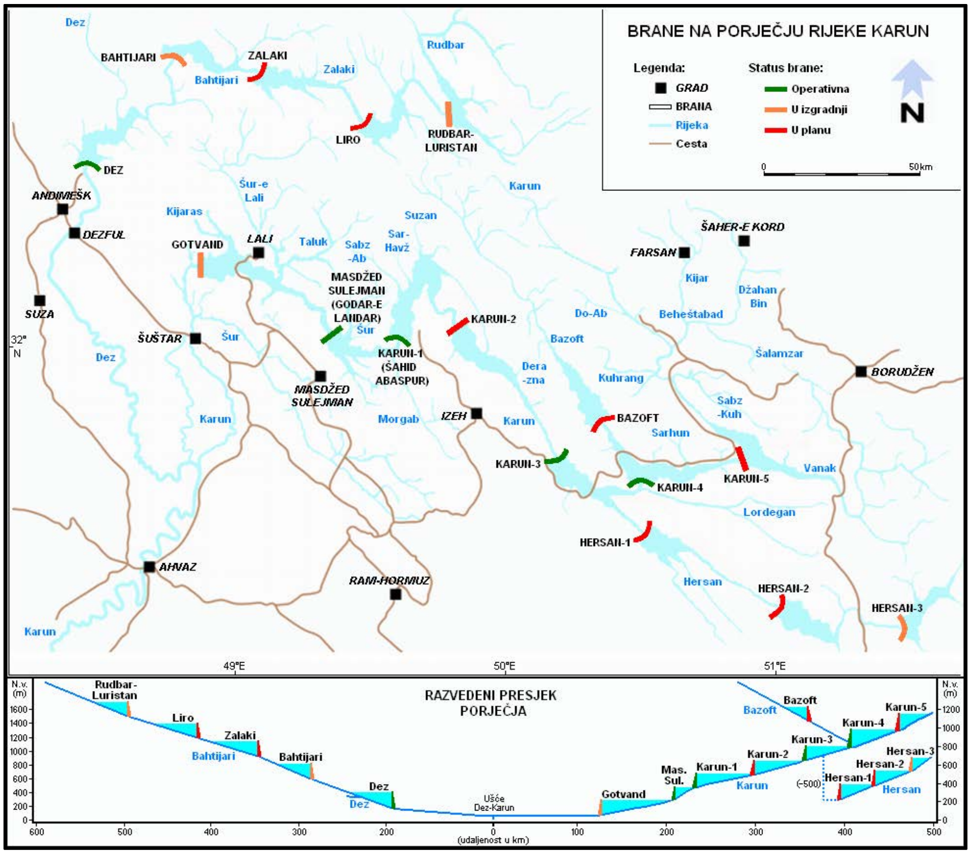
Ilam, Meymeh River (Meimeh river, cropped, CC BY 3.0, khoshtinat).

The southern areas of this basin are areas with high temperatures and large cities (Abadan in Iran and Basrah in Iraq). Adjacent waters are highly polluted with sewage, agricultural waste and other chemicals (e.g., see DouAbul *et al*., 1988; Diagomanolin *et al*., 2004; Karamouz *et al*., 2005; Afkhami *et al*., 2007). The increased use of motor boats has led to oil pollution. DDT is still sprayed against malarial mosquitos on stagnant pools adjacent to the main river course leaving a brown stain on the rocks (observations in 1995; a letter of complaint to the appropriate agency carrying out this spraying by the Iranian Fisheries Research and Training Organization elicited no response). Scott (1995) recorded sale of chloridrin, a persistent insecticide, to residents of the Hawr al Hoveyzeh region in Iran as a means of poisoning large numbers of fish for sale. Phytoplankton blooms are common and in canals the chlorosity increases, transparency decreases and pH reduces because of the dying plant material. The Shatt al Arab is more affected by physical factors, as it is an estuary. Historical problems with salinisation of soils (and

presumably water) extend back 5,000 years in southern Mesopotamia including Khuzestan, a consequence of over-irrigation and inadequate drainage (Goldsmith and Hildyard, 1984). The irrigation systems rose and fell with the vicissitudes of history. There was a large-scale irrigation network in Khuzestan during the Sassanian period (A.D. 226-639), lost through conflict and natural disasters after this date and reconstructed in modern times (Adams, 1962).

An article in the Guardian (www.theguardian.com/world/iran-blog/2015/apr/16/iran-khuzestan-environment-wetlands-dust-pollution) detailed environmental changes in Khuzestan, including toxic waste in rivers, drying of rivers, diversion of water from the Karun River to the Zayandeh River and to Qom, Yazd and Kerman, dam construction, dust storms, oil extraction, sugarcane agribusiness and its heavy demands on water and its pesticides and soil salinisation, and escapes of tilapia from fish farms affecting native fishes, particularly cyprinoids. Valiallahi (2018) also noted the potential threat of tilapia to *Barbus* and other species in the Zagros Mountains of Iran.

Dams are an important habitat for fishes in the Tigris River basin. Partow (2001) listed 18 dams in the Tigris basin of Iran, either constructed or planned, and these will affect the environment markedly in changing flow regimes, impounding water and eliminating fluvial habitat, removing silt, affecting temperature downstream, causing salinisation as return water from irrigation projects flows back into rivers, and so on. The Karkheh Dam was even planned to carry water via pipeline over land (330 km in length) and under the sea (210 km) to Kuwait. The supply rate would be 200 million gallons per day (Partow, 2001) or 300 million cu m (www.irna.com, downloaded 29 January 2003). Development of dams in the Karun-Dez watershed is depicted below and is mirrored in other parts of this basin and in Iran generally where water supplies are available




Karun-Dez watershed dams, March 2012
(labels in Croatian; green operational, orange in development, red in plan;
with elevation and distance below)
(Karun-Dez watershed Dams Cro, CC BY-SA 3.0, Orijentolog).

The Qeshlaq, Gheshlagh, Sanandaj or Vahdat Dam near Sanandaj on the Qeshlaq River has a fauna including the cyprinoids *Alburnus mossulensis* (= *A. sellal*), *Barbus lacerta*, *Capoeta damascina* (*sic*, identity uncertain), *C. trutta*, *Carassius auratus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Garra rufa*, *Hemiculter leucisculus*, *Hypophthalmichthys molitrix*, *H. nobilis*, *Luciobarbus barbulus*, *Pseudorasbora parva*, *Rutilus kutum*, *Squalius cephalus* (= *S. berak*) and *S. lepidus* (Barzegar and Jalali Jafari, 2006; Bozorgnia *et al*., 2012; Bahrami Kamangar *et al*., 2012a). Thirty species of parasites were found on this fauna, notably *Ligula intestinalis*, which is detrimental to native and food fishes and a possible public health threat (Ahmadiara, 2017). Maleki *et al*. (2019) recorded helminth parasites on nine species of fish from the Qeshlaq River and Dam namely the digenean trematodes *Allocreadium* sp., *Clinostomum complanatum* and *Posthodiplostomum* sp., the tapeworms *Khawia armenica* and *Schyzocotyle acheilognathi*, the monogeneans *Dactylogyrus hypophthalmichthys* and *Paradiplozoon* sp. and an acanthocephalan *Pallisentis cholodkowskyi*. *Cyprinus carpio* and *Hypophthalmichthys molitrix* were the most abundant fishes in this mercury-polluted reservoir and larger fish over 850 g had mercury levels greater than established limits for human consumption (Khoshnamavand *et al*., 2013). The dam is eutrophic with algal blooms at the end of spring, and the river is mesotrophic below the dam (Rezaei *et al*., 2012). Water quality in the dam was lower than upstream and downstream and mercury levels were nine times higher than the maximum acceptable concentration (Rezaei *et al*., 2013).

Kordestan, Qeshlaq Dam
(Lake of Sanandaj Dam …., CC BY 3.0, Hadi Karimi).

The Azad Dam west of Sanandaj is 115 m high with a capacity of 260 million cu m. The dam is mesotrophic, and eutrophic to hypertrophic at some bottom layer stations (Makhlough *et al*., 2017). Nasrollahzadeh Saravi *et al*. (2017, 2020) examined physico-chemical parameters and found the reservoir suitable for aquaculture of Cyprinidae (cyprinoids). Roohi *et al*. (2018) estimated fish production capacity at 218 kg/ha based on the primary production. The dam was oligotrophic to oligomesotrophic but would become eutrophic with increased aquaculture activity. Naderi Jolodar *et al*. (2020) sampled fish in the reservoir and found 12 species including *Sasanidus kermanshahensis* (Nemacheilidae), the exotic cyprinoids *Hemiculter leucisculus*, *Hypophthalmichthys molitrix* and *Pseudorasbora parva*, and seven cyprinids namely *Barbus lacerta*, *Capoeta saadii* (*sic*, *Capoeta* sp., as this species is not found in this area unless introduced), *C. trutta*, *Carassius auratus*, *Cyprinion macrostomus*, *Cyprinus carpio* (an exotic) and *Garra rufa*, and one leuciscid namely *Alburnus sellal*. The size and weight of the population in the lake habitat of the dam were significantly higher than in the habitat of the Komasi River on which the dam lies.

The Gawshan or Gavshan Dam is located at Kamyaran near Kermanshah on the Gaweh River and was scheduled for completion in 2002. The dam will be 136 m high and the complex includes a 19 km long tunnel for water transfer (http://netiran.com/news/IranNews/html/94111305INEC.html). Other dams include the 40 million cu m Zaribar Dam in Marivan and the 563 million cu m Kavoshan Dam 35 km south of Sanandaj (http://netiran.com/news/TehranTimes/html/95111803TTPL.html).

The environmental conditions in a headwater dam, the Hanna Dam on the Hanna River in the Karun basin, were described by Esteky (2001) and Daniali *et al*. (2015, 2017) and fish production in the river by Estoki (2000). Two-thirds of the reservoir was covered by macrophytes and, with their decomposition ammonia levels in winter and spring, and nitrite in summer and autumn, exceeded allowable levels and could affect fish growth and survival. *Oncorhynchus mykiss* (rainbow trout) culture caused oxygen depletion near farms.

The Dez (formerly Mohammed Reza Shah Pahlavi) Dam on the Dez River at 32°38'N, 48°28'E and 26 km north of Andimeshk, opened in 1963 and is 203 m high with a reservoir capacity of 3,350 million cu m, reduced to 2,600 million cu m by 2006 from siltation, and has a maximum surface area of 4,000 ha. Surface water temperatures can exceed 30°C while at 50 m

plus depths it is 15-16°C in summer. Assar *et al*. (2014) gave details of water quality, listed as good to excellent. Its original life span was estimated at 100 years but this had to be reduced to less than 50 years because of the rapid accumulation of sediment from erosion. Sediment deposition prevents development of a bottom fauna and steep banks with water fluctuations limit vegetation. Nümann (1966, 1969) gave some limnological information on this reservoir. Nümann (1966) recommended introduction of the leuciscid *Acanthobrama terraesanctae* and the cichlid *Tilapia galilaea* from Israel to the reservoir, and later *Sander lucioperca* (pike-perch) and even trout. Sabzalizadeh (2006) gave a description of the ecology of this reservoir and Eskandari *et al*. (2007) a description of fish populations. *Barbus* (= *Luciobarbus*) *esocinus*, *Barbus* (= *Arabibarbus*) *grypus* and *Capoeta trutta* were the most numerous species and the fauna included the exotics *Carassius auratus*, *Hypophthalmichthys molitrix* and *Oncorhynchus mykiss* (rainbow trout).

The Karkheh Dam, 20 km northwest of Andimeshk, opened in 2001, has a crest 3,030 m long, a height of 127 m and was the sixth largest dam in the world with a capacity of 7.8 billion cu m, nearly a third of the total dam capacity for the country. In 2014 the maximum water in the reservoir was 1.9 billion cu m because of drought. The dam was meant to produce electricity, to be used for fish farming, and used to control floods and drought (*Islamic Republic News Agency*, 17 April 2001, 19 April 2001; *Aftab Yazd*, *Tehran*, 346, 18 April 2001, 7 pp.; Sadegi, 2003). Alipour and Nohani (2014) and Naderi *et al*. (2014) gave details of flow simulation for the fishway at the Karkheh Diversion Dam at Hamidieh.

Khuzestan, Karkheh Dam,
(Karkheh Dam …., CC BY 3.0, Hadi Karimi).

There is also the Upper Gotvand Dam opened in 2012 on the Karun River, 30 km north of Shushtar near Gotvand. It is 180 m high with a reservoir capacity of 4,500 million cu m, making it the second largest dam in Iran (*sic*) (*Islamic Republic News Agency*, 25 January 2000). The dam tapped salt domes and increased the salinity of the Karun River (Mansournejad *et al*., 2015).

Khuzestan, Upper Gotvand Reservoir
(UpperGotvandReservoirJune-2016, CC BY-SA 4.0, Rehman Abubakr).

The Lower Gotvand Dam at 22 m high diverts water for irrigating farmland. The 205 m high Karun-3 Dam near Izeh with a total capacity of 2,970 million cu m, to be completed in the year 2001 (filling actually started in 2003 - www.netiran.com, downloaded 15 November 2004), is a major hydroelectrical plant as is the 200 m high Karun-1 Dam (Shahid Abbaspour, formerly Reza Shah Kabir) 25 km northeast of Masjed-e Soleyman (http://netiran.com/news/IranNews/html/95040822INPL.html) completed in 1976 with a capacity of 3,139 million cu m. Eghisad *et al*. (2019) noted impacts of the Karun-3 Dam included increasing aquatic mortality and decreasing aquatic diversity. The Karun-4 Dam at 31º36'N, 50º28'E opened in 2011 with a 230 m high dam and a capacity of 2,190 million cu m. It will produce electricity and regulate river flow for industry and agriculture by controlling floods. However, a study by Akbarian Aghdam *et al*. (2015) found climate change (rainfall decrease and temperature increase) would result in a decrease in river discharge as high as 32% over the next 90 years.

Chahar Mahall and Bakhtiari, Karun-4 Dam
(Karoon4 lake dam 4, CC BY 3.0, Farid Atar).

A major dam was also planned at Shushtar (*Islamic Republic News Agency*, 26 September 1998). A tunnel was planned from the Dez River to Golpayegan to supply water to Markazi Province in central Iran (www.iranmania.com, downloaded 19 January 2004). An environmental risk assessment was carried out on the Bala River Dam located between the Karkheh and Dez rivers in Khuzestan by Jozi *et al*. (2010).

Khuzestan, Karun-3 Dam
(Karun3-dam, CC BY-SA 3.0, Zereshk).

A giant dam was planned for the Simareh (*Islamic Republic News Agency*, 26 September 1998) and opened in 2013. It is 180 m high and has a surface area of 69.5 sq km.

Ilam, Simareh Dam,
(Sad-e-seymareh, CC BY-SA 3.0, Alinm994).

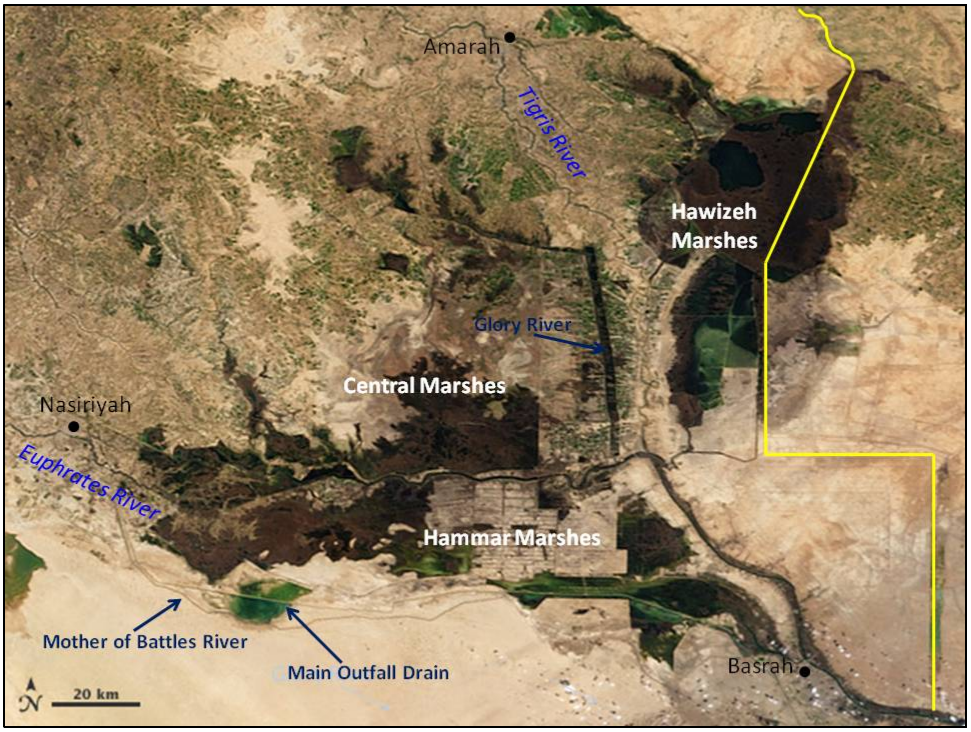
The Marun Dam northeast of Behbehan was scheduled for completion in 1996 with a crest of 345 m (*Islamic Republic News Agency*, 11 November 1998) but was to be completed in 2004 with a crest of 175 m and containing 1.2-1.3 billion cu m of water (*Islamic Republic News Agency*, 12 January 1999; 5 February 2002).

Khuzestan and Kohgiluyeh and Bowyer Ahmad, Marun Dam
(Marun Dam 2019-06-08 10, CC BY 4.0, Mehdi Pedramkhoo).

There are also four diversion dams on the Marun and one of these, the Jazaeen, has a fishway but fish are trapped downstream of it during their migration (*sic*) (Kurdistani and Bajestan, 2004). Other dams in this system lack a fishway. Later Kurdistani and Bajestan stated that there are no migratory fishes in the Marun, only resident species (which presumably undergo local movements blocked by dams). They mentioned *Barbus* (= *Arabibarbus*) *grypus* and *Barbus pectoralis* (probably *Luciobarbus barbulus*) as the affected species. The Jareh Dam on the Zard River northeast of Ramhormoz dates back to the Sassanid era and is still in use (*Islamic Republic News Agency*, 26 June 2000) although it will be submerged on construction of a modern dam.

Historical changes have occurred in this basin, presumably affecting the fish fauna. Canals and other irrigation structures have long been a feature of the Mesopotamian plains, forming habitats for fishes dating back thousands of years (Bagley, 1976). Their loss through natural and man-made disasters must have affected fish populations but sufficient natural habitat no doubt remained to ensure survival. The construction of dams upstream in Turkey (and see below), and the large scale, modern drainage programmes in Iraq bordering Iran such as the Three River Project, are drying up the extensive marsh systems, and these are regarded as an eco-disaster leading to desertification in Iraq and adjacent regions of Iran (North, 1993; Pearce, 1993, 2001; Ryan, 1994; National Geographic, 185(4):unnumbered page, 1994; Scott, 1995; Munro and Touron, 1997; Maltby, 1999; Partow, 2001; www.amarappeal.com/documents/Draft_Report.pdf, downloaded 15 November 2001). The 32 km long Fish Lake was constructed as a barrier to Iranian attacks on Basrah. The Iranians dug several drainage ditches from Fish Lake northeast of Basrah to the Karun River, to dry up land for infantry attacks on Basrah. This whole marsh area of about 17,000 sq km is the most important wetland in the Middle East and one of the top 10 in the world. The Central and Al-Hammar marshes in Iraq by 2001 have had 97% and 94% of their land converted into bare ground and salt crusts. Less than one-third of the Hawr al Hawizeh (= Hawr al Azim in Iran) survived. It was estimated in the 1990s that the marsh area would be a desert within a decade and

this seems to have been an accurate assessment. The effects on the fishes in Iran were unknown but much habitat was lost which could have served as a reserve against loss in Iran through natural and man-made changes. Mirsanjani and Karami (2018) compared Landsat images of this wetland from 1991 to 2016. Agriculture, energy production, hydro-politics and geopolitical considerations all affected the wetland. However, conditions in 2016 compared to 2013 showed the amount of vegetation and water increased, so some recovery is possible.



Iraq marshes with Iranian border in yellow
(CC0, NASA).

The Iran-Iraq War of 1980-1988 severely damaged the Hawr al Hawizeh in Iraq, and presumably to some extent in Iran. Bombs and shells, chemical weapons, pollution, burning of reed beds, reed cutting and armoured boats used to smash through obstructing reeds all had deleterious effects (Scott, 1995). The Iraqi shores of this hawr were drained by dyke construction and river control presumably for military reasons in this border area. Some marsh will survive in Iran because it is fed from wholly Iranian rivers but *Iran News* (19 February 1995) reported that draining of Iraqi marshes will lead to desertification inside Iran. Details on the restored Hawizeh Marsh and its fishes in Iraq are found in Mohamed *et al*. (2008) and Abd *et al*. (2009).

The Southeast Anatolia Project (known as GAP after its Turkish acronym) incorporates 21 dams and 19 hydroelectric facilities including the massive Ataturk Dam on the Euphrates completed in 1993. It planned to draw off one-third of the waters originating in Turkey and would use water from the Tigris River (Morris, 1992; Biswas, 1994; *Ottawa Citizen*, 10 November 1994; Beaumont, 1998). The reduction in flow for Iraq may reach 60%, especially when water is taken from the Euphrates or ath-Thawrah Dam (its reservoir is Lake Assad) at Tabqa in Syria (Vesiland, 1993). This will have major downstream effects, less so in Iran than in Syria and Iraq, but flow into the Shatt al Arab shared between Iran and Iraq will be greatly decreased perhaps allowing greater penetration of saline water and restricting migrations of

fishes.

In the more distant past, other alterations to the environment have been postulated. A theory was advanced that the silt-laden discharge of the Tigris-Euphrates-Karun rivers has built out a delta into the Persian Gulf. The head of the Gulf would have reached Baghdad and Samarra about 7,000-6,000 B.P. and since then the land area is supposed to have extended some 200 km southward. The present plains would not then have been as extensive and rivers from Iran would have entered directly into the Gulf. The Admiralty Naval Staff (1918), Mason *et al*. (1944), Adams (1962), Hansman (1978), Maltby (1994) and Lambeck (1996) provided illustrations of this recession of the head of the Persian Gulf in historic times along with details of historical and archaeological evidence. The sea coast was then supposedly as far inland as Ahvaz in Iran for example. Lees and Falcon (1952) proposed that in fact down warping occurs under the weight of sediment. Certainly, the silt load has not built up a land surface. The coastline, under this theory as interpreted by Fisher (1968), has been constant since the end of the Pliocene and presumably as a marsh habitat for fishes too. However, Lees and Falcon stated that there were advances and retreats through historic and prehistoric time. Ionides (1954), Larsen (1975) and Nützel (1975) refuted Lees and Falcon and maintained that marine clays and silts indicated a marine embayment as far inland as Amara in Iraq (31°50'N, 47°09'E), and that the third millennium cities of Ur and Eridu had left cuneiform sources placing them on the sea although now they are 100 km from the head of the Persian Gulf. Lees and Falcon did not take into account sea level changes such as the postglacial rise of 100 m and interglacial rises of 30-100 m. Active growth of a delta at the head of the Gulf over the last 20,000 years may only have occurred from 10,000 to 2,000 B.P. and again in the last 300 years. Subsidence levels are probably not as great as postulated (Vita-Finzi, 1978). Nevertheless, there were probably marshes to the north and they may have just become more available and extensive in recent centuries (Aqrawi, 2001). As Larsen and Evans (1978) and Wagstaff (1985) pointed out, the Persian Gulf shoreline at the head of the Gulf has been affected by, and rendered difficult to interpret, by a complex of factors including confusion of marine and freshwater fossils in an estuarine environment, subsidence, eustatic sea level fluctuations, local seismic activity, climate and therefore hydrologic changes, and cultural changes such as irrigation. Jacobsen (1960) detailed some of the changes in the courses of rivers and canals, based on evidence of ancient settlements that were presumed to be linearly arranged along watercourses. Mallowan (1964) also mapped some ancient river courses. The fish fauna has evidently had to cope with a changing availability of habitat through the post-glacial period. Floods and changes in river courses over this time have no doubt facilitated movement of fishes between Iran and the Tigris-Euphrates basin. It seems unlikely that the separate entry of rivers from Iran into the Gulf would have led to isolation of the faunas to any significant degree.

## Endorheic Basins

### Bejestan

This basin comprises the drainages of the eastern highlands north of Birjand (32°53'N, 59°13'E) flanked by the Dasht-e Kavir basin to the west, the Dasht-e Lut and Sistan basins to the south, the Hari River to the north and the Afghan border to the east. The type localities of *Capoeta fusca* and *C. nudiventris* (= *C. fusca*) lie in this basin and possibly a type locality for *Discognathus rossicus* (= *Garra rossica*) is in this basin too.

Bejestan basin
(in part, on other maps extends further west and south)
(IranCatchEast1, CC BY-SA 4.0, Mahdy Saffar).

The Hari basin is separated by three ranges, from west to east, the Kuh-e Sorkh (35°30'N, 58°36'E) at 3,017 m, the Kuh-e Bizak (35°11'N, 60°20'E) and the Kuh-e Khvaf at 2,517 m east of Khvaf (34°33'N, 60°08'E). These receive snow in winter from moist Caspian Sea air. The highlands are relatively low compared with other parts of Iran and nowhere exceed 3,000 m except for the Kuh-e Sorkh. The lowest points are in the sumps on the Afghan border at about 610 m. There are a number of minor sumps and the drainage patterns have been described as indeterminate. The total area is about 82,000 sq km. Tectonism commonly causes drainage disruptions (Krinsley, 1970).

The distinction of the western parts of the basin from the Dasht-e Kavir basin is somewhat arbitrary since the Kavir-e Namak near Bejestan (34°31'N, 58°10'E) lies at a similar level to the Kavir-e Bozorg and is separated by only a low rise in the land. This kavir receives intermittent streams from the east and north. The Bejestan basin does receive tributaries from Afghanistan but these are minor and do not begin to approach the input received by the Sistan and Hari basins from the east. Streams drain mostly to the east, to three small terminal basins straddling the border; from north to south these are the Namakzar-e Khvaf, the Daqq-e Patargan and the Daqq-e Tondi. The type locality of *Capoeta gibbosa* (= *C. fusca*) lies in the Namakzar-e Khvaf basin and a type locality of *Garra persica* may be in the Daqq-e Tondi basin.


Namakzar and Patargan salt lakes on Iran-Afghan border
(CC0, NASA).

The Dasht-e Lut basin to the south is separated by the drainage divide of the Birjand-Qa'in highlands, which trend north-west to south-east. Kuh-e Kalat is at 2,605 m (34°18'N, 58°22'E) in the north-west and altitudes of 2,779 m are reached in the south-east.

This whole basin has seasonal streams and a few springs with qanats a prominent feature. Water temperatures in qanats are 22-25°C year-round and there is little fluctuation in water flow and chemical composition. Springs in contrast are influenced by the local geology and have a variable chemical composition, as well as being influenced by climate and pollution (Ruttner-Kolisko, 1964, 1966).

Caspian Sea

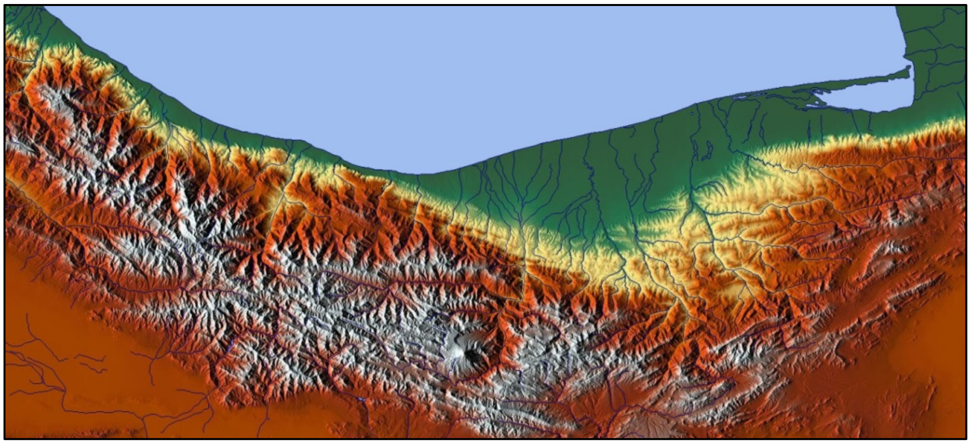
"The Caspian sea is marueilous full of fish, but no kind of monstrous fish, as farre as I could vnderstand, yet hath it sundry sortes of fishes which are not in these parts of the world" ----- Principal Navigations, Voyages, Traffiques and Discoveries of the English Nation, Richard Hakluyt, 1599.

"No sea, perhaps, in the world, produces so great a quantity of fish" ----- said of the Caspian Sea by J. M. Kinneir, 1813.

"Thus a man told me that the Caspian Sea, (on the shore of which we conversed) was a *Maaden-i-mahi* or mine of fish" ----- Sir William Ouseley, 1819.

The Caspian Sea (Darya-ye Khazar, Darya-ye Mazandaran) basin is here taken to include both the rivers draining to that sea and the sea itself within Iranian territorial waters. This basin, in its land part, is elongate, extending from the Turkish border almost to the Afghan border and only acquires some width where the Sefid River and its tributaries penetrate the Alborz Mountains in the west and near Gorgan Bay in the east.

Caspian Sea basin
(IranCatchMaz0, CC BY-SA 4.0, Mahdy Saffar).



Relief Map of Mazandaran and Golestan, eastern Caspian Sea, showing narrow and broad coastal plains,
(Mazandaran Relief Map, CC BY-SA 3.0, Hans Braxmeier).

Mazandaran, Caspian Sea at Mahmudabad,
(Mahmudabad, Mazandaran 04, CC BY-SA 4.0, Mostafameraji).

Mazandaran, Caspian Sea shore east of Nowshahr, with Hamid Assadi
and Sylvie Coad, 4 July 1978, Brian W. Coad.

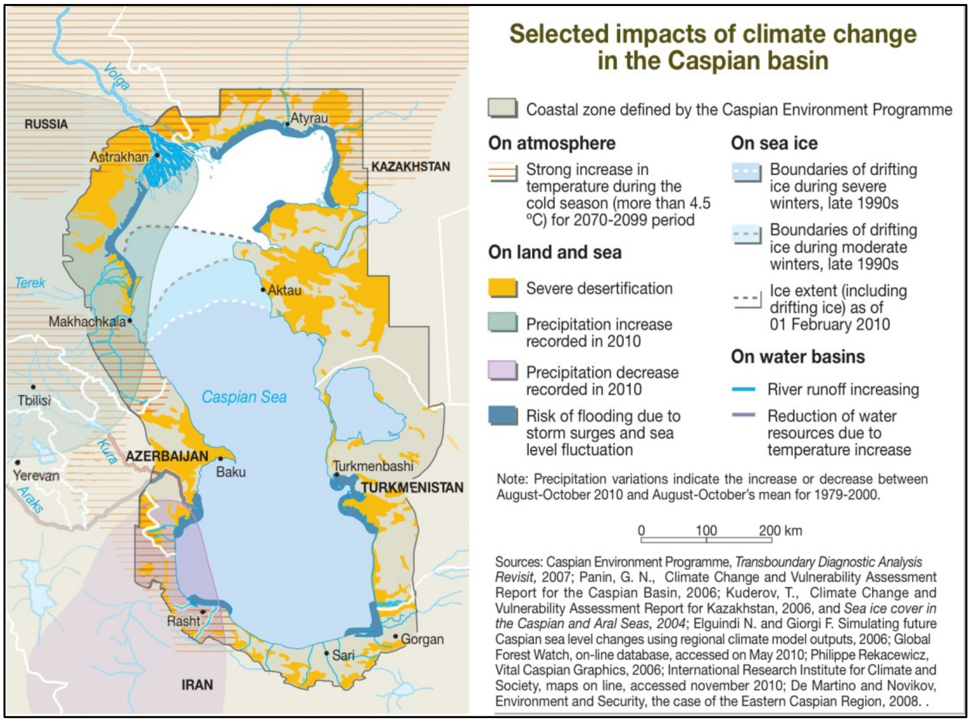

Caspian Sea basin
(GRID-Arendal, UNEP, www.grida.no/resources/5732,
Ieva Rucevska and Philippe Rekacewicz).

According to Pirnia (1951) the Caspian basin in Iran (excluding the sea) encompasses 182,100 sq km while according to Zakeri (1997) this figure is 256,000 sq km, 15.5% of the whole country. Zakeri (1997) recorded 864 small and large rivers, including the Sefid River with a catchment of 67,000 sq km. Much of the information on the Caspian Sea itself was restricted in the past to waters of the former U.S.S.R. and there was relatively little on Iranian territorial waters. However, Dalvand and Lahijani (2015) analysed research by Iranian scientists on the Caspian Sea from 1992 to 2013 based on 323 papers, and showed significant growth in this period. Zenkevi(t)ch (1957, 1963) and Barimani (1977) have reviewed the geography, hydrology and biology of the Caspian Sea, Moiseev (1971) summarised the living resources of the whole sea, Karpinsky (1992) aspects of the benthic ecosystem, and Knipovich (1921), Iljin (1927), and Nevraev (1929) gave accounts of Iranian coastal waters and regional fisheries in the early twentieth century. Mamaev (2002) is a recent general overview. Rozengurt and Hedgpeth (1989), Kosarev and Yablonskaya (1994), Mandych (1995), Golubev (1996) and Ivanov (2000) summarised much of the recent Soviet literature, general reviews were given by Mamaev (2002) and Rucevska (2006), and Bogutskaya *et al*. (2008) reviewed early investigations of the sea and its fish biodiversity with special emphasis on the 1904 expedition led by N. M. Knipovich. Naseka and Bogutskaya (2009) reviewed the whole ichthyofauna and Esmaeili *et al*. (2014) the ichthyofauna of the Iranian portion. Huseynov (2011) gave a popular account of the sea, its fauna, pollution and climate change effects. Kiabi *et al*. (1999) described the wetlands and rivers of Golestan Province at the southeast corner of the Caspian Sea. Gandomi *et al*. (2012) gave a habitat mapping for the Golestan coast and Hoseinzadeh *et al*. (2013, 2016) for part of the Mazandaran coast, an important tool for conservation. Forouhar Vajargah and Hedayati (2021) surveyed the water resources and watershed of Golestan Province. Fendereski *et al*. (2014) provided a biogeographic classification of the sea although the two fish species used in the analysis were not cyprinids or leuciscids. The middle/southern Caspian was well delimited from the northern Caspian and shallow nearshore waters from offshore waters in the south or Iranian waters. Differences in ecoregions were related to climate, distance from rivers, water depth and currents. Hashemi (2021a, 2021b) briefly outlined the need to create marine protected areas for the sustainability of the Caspian Basin and the conservation of riverine functions at the landcape level.

Nasrollahzadeh Saravi (2013a, 2013b) studied the characteristics of the water based on 480 samples in the southern Caspian Sea at eight transects from depths of 5, 10, 20, 50 and 100 m (Astara, Anzali, Sefidrud, Tonekabon, Nowshahr, Babolsar, Amirabad and Bandar-e Torkeman) during 2009-2010. Mean water temperatures were 18.67±0.32 and 17.82±0.43°C at the surface and the euphotic layer, respectively. Minimum and maximum water temperatures were recorded in winter (6.4°C) and summer (27.6°C). In addition, the temperature gradient ranged between 12 to 15°C in 50 and 100 m depths. Mean salinity was 11.04±0.17 g/l at the euphotic layer. Temperature and salinity were positively correlated and, therefore, maximum salinity was recorded in summer and the minimum in winter. The mean transparency was 4.35±0.21 m which compared to a previous sampling period (2008) showed a small decrease. The mean of pH was 8.43±0.01 which was higher than that previous sampling period. The mean dissolved oxygen and percent dissolved oxygen were 5.72±0.06 ml/l and 130±1% at the euphotic layer. The mean percent dissolved oxygen was 104±5% at the euphotic layer in 1996 (before the introduction of the comb jelly, *Mnemiopsis leidyi*), but studies in the years 2004, 2008 and the present (one decade after introduction of *Mnemiopsis leidyi*) this value registered higher than 120% at the euphotic layer. Annual mean abundance of biological parameters such as

phytoplankton, zooplankton and *M. leidyi* were 143±12 million cells/cu m, 6,548±700 individuals/cu m and 86±10 individuals/cu m, and for biomass were 548±41 mg/cu m, 60±9 mg/cu m and 5.06±0.65 g/cu m, respectively. Annual mean abundance and biomass of macrobenthos were 5,970±460 individuals/sq m and 44±10 g/sq m, respectively. The trophic status of the Caspian ecosystem shifted from oligotrophy (before the introduction of *Mnemiopsis leidyi*) to meso-eutrophy (after the introduction of *Mnemiopsis leidyi*). Annual concentration of inorganic nitrogen (dissolved inorganic nitrogen (DIN) = $NH^{4+}$, $NO^{2-}$, $NO^{3-}$) had a fairly wide variation. Percentage of nitrogen components out of DIN were varied, 9-98, 0.2-28.2 and 0.0-90.0 respectively. The percentage of DIN was lower than 15% and dissolved organic nitrogen (DON) was higher than 80%. Overall, results showed that water temperature, salinity, transparency and DON were lower than the previous study (2008), but dissolved oxygen, percent dissolved oxygen, pH, $NH^{4+}$, $NO^{3-}$ and dissolved silica were higher than the previous sampling period. Inorganic phosphorus and $NO^{2-}$ had not changed substantially. The nitrogen/phosphorus ratio of the Caspian Sea had a narrow range, an order of magnitude lower than other seas. The results of the studies showed that the Caspian ecosystem was nitrogen limited before the introduction of *Mnemiopsis leidyi*, while it seemed that after the introduction of *Mnemiopsis leidyi* the system shifted to phosphorus limitation. The increase of trophic level from oligotrophic to meso-eutrophic, an increase of percent dissolved oxygen from 105 to 120%, an increase in phytoplankton Shannon index, a decrease in zooplankton Shannon index, entrance of potentially invasive species to the list of dominant phytoplankton species, increase of phyto/zooplankton biomass ratio from less than five to more than 10, and also an increase of deposit feeder species abundance in the macrobenthos, are evidence that indicates a disturbance and stress condition of the Caspian Sea.

Makhlough *et al*. (2014) studied the ecobiology of Mazandaran coastal waters, studying phytoplankton but also summarising environmental parameters. Mirzaei *et al*. (2014) summarised water quality in rivers along the Mazandaran coast, noting western rivers had lower quality. Mitrofanov and Mamilov (2015) reviewed the fish diversity and fisheries on the Kazakhstan coast. Rabbaniha (2016) and Owfi (2016) gave an extensive overview of the environment and ecology of the Golestan Province part of the Caspian Sea related to the development of the fishery potential. Beyraghdar Kashkooli *et al*. (2017) examined climate-driven ecological shifts in the Caspian Sea. Overall Caspian ecosystem structures and functioning might have, at least partially, been impacted by global-scale climatic or local environmental shifts. *Rutilus kutum* was the fish used in these analyses as it covered more than 70% of the annual Iranian coastal catches. Nasrollahzadeh Saravi *et al*. (2019) reviewed climate change with emphasis on the Caspian Sea.



Caspian Sea climate change
(GRID-Arendal, UNEP, www.grida.no/resources/5734, Riccardo Pravettoni).

The Caspian Environment Programme (CEP), Baku, Azerbaijan at www.caspianenvironment.org is an ongoing and developing source of information on this sea, the surrounding land, its history, its management, biodiversity strategy and action plan, and a wide sweep of environmental problems. This site has numerous documents and reports online, some with authors, e.g., Katunin (2000), Ivanov and Katunin (2001), ERM-Lahmeyer International GmbH, DHI Water & Environment and GOPA Consultants (2001a), others appearing under CEP or TACIS (Technical Assistance to the Commonwealth of Independent States, European Union), e.g., TACIS and UNDP (2000), TACIS (2002), Caspian Environment Programme (1998, 2000b, 2002). These reports included information on the fishes and fisheries but are best referred to for the interactions between people and the environment. Razavi (1999) gave an introduction to the ecology of the sea in Farsi. Nezami *et al*. (2000) and Caspian Environment Programme (2001a, 2001b) gave recent general descriptions of the Iranian Caspian coastal zone, the important rivers, wetlands, water quality, climate, pollutants, and fisheries. www.bibliothecapersica.com/articlenavigation/index.html, under Caspian Sea, downloaded 24 December 2004, also gave an overview of this basin. Nadim *et al*. (2006) reviewed the management of coastal areas in the Caspian Sea. Nasrollahzadeh (2010) reviewed the ecological challenges facing this enclosed sea and Allahyari (2010) the social sustainability of fishery cooperatives in Gilan. Motamed (2016) investigated the attitudes and factors affecting participation by fishermen in cooperatives. Nejat *et al*. (2018) reviewed environmental challenges and the responsibilities of littoral states. There is also an extensive literature on the sea available online.

The Caspian Sea is the largest lake or inland water body in the world at 436,284 sq km, a surface area encompassing 18% of the total area of all lakes in the world, about the same area as Great Britain (other surface area figures are 378,400 sq km, 384,400 sq km and 390,000 sq km -

data of this nature varies quite markedly between apparently authoritative sources). The volume is 78,100 cu km, 44% of the total volume of inland lakes of the world. Its north-south extent is 1,204 km and width is 204 to 566 km. The shoreline, including islands, extends for 7,000 km, 1,000 km of which is Iranian. The catchment area is 3.6 million sq km. Dumont (1998) presented arguments for this water body being a true lake and not a sea.

Caspian Sea, with eastern edge of Black Sea on left and Kara Bogaz Gol on right.
Lake Urmia is at the lower left (turquoise) and Lake Van in Turkey lies to its west.
Lake Sevan in Armenia is to the north of Lake Urmia
(CC0, NASA).

North, Middle and South Caspian basins are recognised, divided by shoals. Iranian waters fall within the South Caspian Basin which occupies 148,700 sq km and is separated from the Middle Caspian by the Apsheron Bank. The South Caspian holds over 65% of the sea's water and is the deepest basin, to -1,000 m in depressions, average -325 m. The northern basin holds only 1% of the water.

The sea receives 291 cu km from river run-off and 87 cu km from precipitation but loses 374 cu km from evaporation and 11 cu km to overflow into the Kara Bogaz Gol (Gerasimov, 1978b). The Kara Bogaz Gol (= Black Throat Bay), an eastern arm of the Caspian Sea in Turkmenistan, is 160 km long by 140 km broad (18,389 sq km) but only 2-3 m deep. It acts as a salt precipitator. This water body was blocked off by a dam to conserve the water lost in it by evaporation in 1980. The Caspian Sea has a net annual water deficit of 15 cu km with 5 cu km being lost through the Kara Bogaz Gol alone (Rich, 1982, 1983). However, this resulted in salts being spread by the winds, ruining fish spawning grounds and fish farms in the Caspian basin, and ultimately would lead to the salinisation of the Caspian Sea. A dike has now been constructed to allow some flow into the Kara Bogaz Gol and allow the flushing effect to operate. The refilling process over three years prevented a 35 cm rise in the Caspian Sea level (Dumont, 1995). Use of this water body to reduce level rises in the Caspian Sea and prevent flooding has been proposed (Wardlaw, 2001). Fish which enter the salty Kara Bogaz Gol lose their swimming capacity, become blind and thrashing about often come to lie on the shore. Birds eat them but those that are missed become salted and dried and may be preserved for a year or so. The Turkmenistan government re-established natural flow into the Kara Bogaz Gol in 1992 because of the Caspian Sea level rise (Zonn in Glantz and Zonn, 1997).

Turkmenistan, Kara Bogaz Gol
(CC0, NASA).

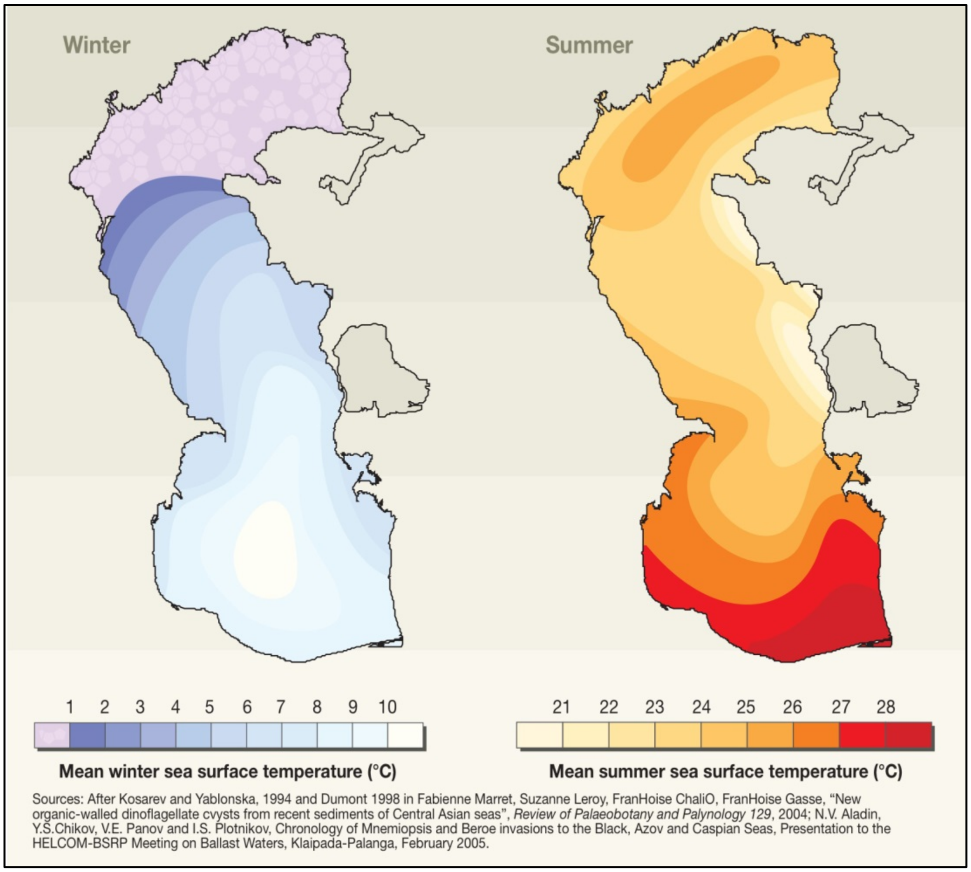

Turkmenistan, Kara Bogaz Gol
(CC0, NASA).

The Volga River accounts for 76.3% (82% according to Dumont (1995)) of the inflow of rivers, the Kura River 4.9%, the Ural River 3.7%, the Terek River 3.2% and the remaining rivers including all those of the Iranian shore 11.9%. Iranian rivers account for only 5% of the Caspian inflow. Iran has 7% of the catchment area, 14% of the coast, contributes 3% of the settling solids, and 2% of the fishery (Badakhshan and Shayegan in Glantz and Zonn, 1997). The Volga has its headwaters near Moscow and is 3,688 km long with a catchment area of 1,360,000 sq km and a mean annual flow at Volgograd of 8,380 cu m/sec. The Volga is of prime importance in the Caspian Sea basin to migratory fishes as a spawning site and the biology of these species has been studied extensively. Often these studies provide the basis for much of the knowledge of Iranian fishes to the south.

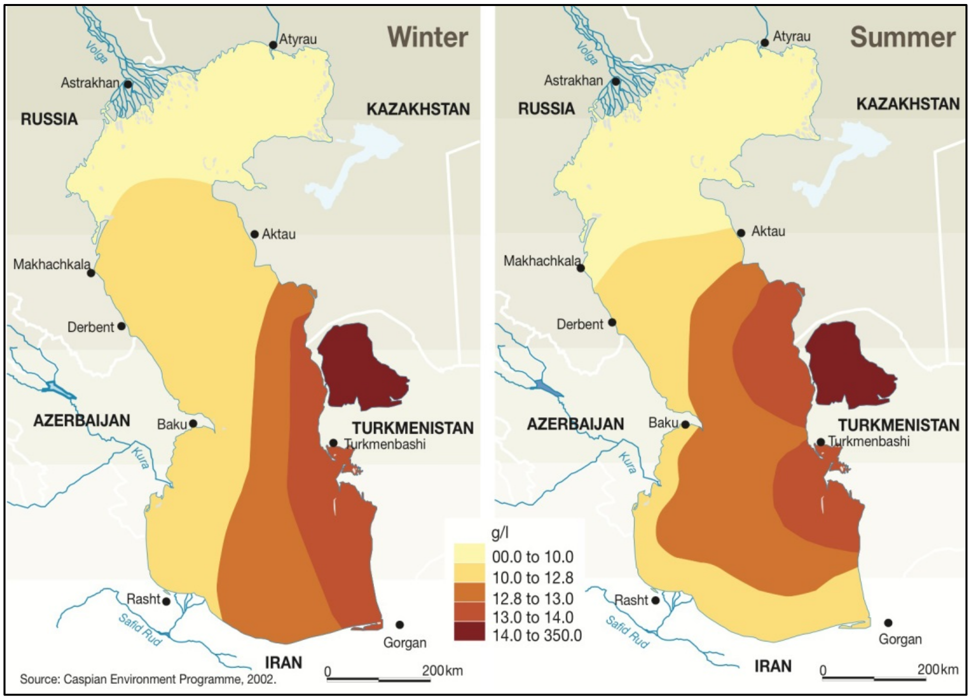
The total Caspian Sea drainage area is said to be 3,700,000 sq km, about 25% of the continental land mass of the U.S.A. (Rozengurt and Hedgpeth, 1989). The basin included about one fifth of the crops and one third of total industrial output of the former U.S.S.R. (Rozengurt and Hedgpeth, 1989). Its northernmost waters are north of St. Petersburg (= Leningrad) in Russia while its southernmost waters rise on the flanks of the Zagros Mountains in Iran. This ranges from the subarctic to the subtropical region and is very diverse in climate and geology. Natural runoff in the South Caspian Basin ranges from 8 to 18 cu km while in the North Caspian it is 207-375 cu km. However, the North Caspian is very shallow (mean 4-5 m, maximum 20-25 m) compared to the south Caspian (mean 325-334 m, maximum 980-1,025 m). This is also reflected in the volume, 400-700 cu km compared to 49,000-77,500 cu km. Salinity is about 12-13‰, increasing in isolated bays and decreasing near river mouths. Summer temperatures in the south reach 27°C, and in winter 9°C, but the northern parts ice over. The Gorgan River area has reached 30.9°C (Laloei, 2006). Surface water temperatures for the South Caspian are reported as 7.0-10.3°C in winter, 7.9-14.0°C in spring, 25.0-29.0°C in summer and 12.0-19.0°C in autumn (Rozengurt and Hedgpeth, 1989). These authors also reported salinity ranges of 12.5-13.0, 12.3-

13.2, 12.6-13.6 and 12.3-13.5‰ for the same seasons, oxygen levels of 7.0-7.8, 7.0-8.2, 5.0-6.0 and 6.0-8.0 ml/l, and pH values of 8.48, 8.44, 8.44 and 8.50.

North Caspian Sea, bright blue probably due to a mixture of plant life and sediment stirred up by moving water, Volga River mouth on upper left and and Ural River mouth upper centre
(North Caspian Sea, MERIS, 22 September 2003 ESA222068, cropped,
CC BY-SA 3.0 IGO, European Space Agency).




Caspian Sea mean surface temperatures
(Philippe Rekacewicz (le Monde Diplomatique) assisted by Laura Margueritte and Cecile Marin, later updated by Riccardo Pravettoni (GRID-Arendal), Novikov, Viktor (Zoi Environment Network), www.grida.no/resources/5734, UNEP).




Caspian Sea surface salinity
(Philippe Rekacewicz (le Monde Diplomatique) assisted by Laura Margueritte and Cecile Marin, later updated by Riccardo Pravettoni (GRID-Arendal), Novikov, Viktor (Zoi Environment Network), www.grida.no/resources/5734, UNEP).

Vertical mixing occurs down to 50-150 m in the South Caspian (Mellat-Parast, 1992). There is little oxygen below 200-300 m and no fish life although changes to the hydrological regime of the Volga have increased aeration and oxygen content of deeper layers in the south Caspian, down to 600-800 m. The Caspian has no tides but sustained winds can cause seiches, local and temporary rises in sea level. There is a current along the Iranian shore from west to east. The shelf along the Iranian coast is narrow (6-10 km) and steep (Kosarev and Yablonskaya, 1994). Beaches are usually sand with shell gravel on the bottom further out. The extreme western coast has some shingle beaches and west of Alamdeh in the central part is some rocky shore but there are no major cliffs or headlands. The shore has coastal dunes, spits and bars with lagoons inland, either brackish or fresh, grading into the higher and dryer foothills. Water 10 m deep or shallower has a bottom of sand and gravel while at greater depths of 50-100 m clay and softer sediments increase. There is more sand in these greater depths off Gilan compared with off Mazandaran.

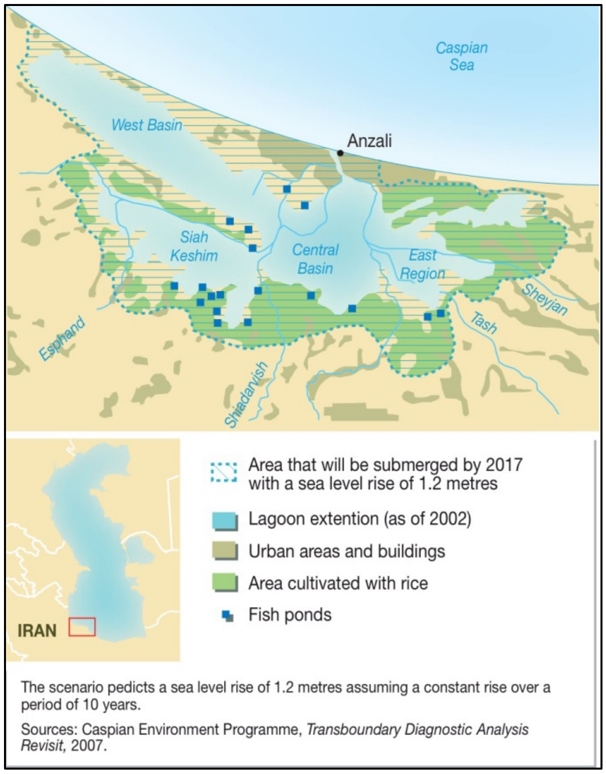
Water balance for this sea depends on a delicate balance of inflow, evaporation, precipitation, climate, and abstraction for human needs.

The rise and fall of sea level in the Caspian had major effects on the current fish fauna and on how fish reached the Caspian. Maximum depth is 1,025 m, mean depth is 184 m, and depth below sea level is -28 m (-27.66 m averaged over the past 2,500 years according to Dumont (1998)). There are natural water level fluctuations - the figure cited is from 1983; in 1978 it was -29.02 m, the lowest recorded since observations began (Voropaev and Velikanov, 1985). Petr (1987) has pointed out that a decline below -28.5 m would result in a change in salinity distribution and in water currents mixing riverine and sea water. A decline in productivity would follow. A fall of only 1 m would cause a 60% reduction in fish food supply

and, since this fall poses barriers to migration to better feeding grounds, a further 20% loss in food supply. Recently however, since 1978, the sea began to rise, by 2.1 m from 1978 to 1993 to -26.95 m, with a possible rise of 3 m in the next 25 years. Borghei and Vaziri (1995) gave an average rise of 1.2 cm a month for the period 1986-1993. The sea rose 26 cm in 1994. However, over the past 2,500 years the sea level has not exceeded -25 m and is not anticipated to do so in the near future; the level is cyclical (Rychagov, 1997; Gorji-Bandpy and Hooman, 2004). The reason for the rise is probably a climatic shift (Mandych, 1995; Shayegan and Badakshan, 1996; Kobori and Glantz, 1998) but a sheen of oil from pollution may be helping in the reduced evaporation of 7-10% observed over two decades. Tectonic shifts of the sea floor may also be a contributing factor. Predictions of water level changes have proved unreliable so schemes to ameliorate rises or falls are unwarranted and could be catastrophic (Abuzyarov, 1999). Georgievskiy (2001) however, predicted a lowering of the sea level to -27.6 to -28.9 m by the year 2030 from -27.0 m in 2000. Klige and Myagkov (1992) examined the water balance of the Caspian Sea and predicted a rise in sea level to 1995-1997 and then future declines of the order of several metres in the following century.

The rise in water level engulfed buildings including industrial sites which polluted the waters of the Caspian further. Iranian towns and cities damaged included Babol Sar, Tonekabon, Ramsar, Ashuradeh, Bandar-e Torkeman, Anzali, Astara and Kolachai (Zonn in Glantz and Zonn (1997)). Fish caught near Nowshahr in 1999 were contaminated with oil pollutants (*Tehran Times*, 1 November 1999). The complex of chemical, petrochemical and metallurgical plants at Sumgait near Baku in Azerbaijan produced 335,000 tonnes of mostly toxic waste including dioxins. Hundreds of waste lakes of oil near Baku were being slowly engulfed by the rising Caspian. Nasrolazadeh Saravi (2001) and Khatoonabadai and Dehcheshmeh (2006) described oil pollution in Iranian coastal waters although it was much less than near Baku, particularly in Mazandaran and Golestan. Heavy metals entered down the major rivers from mining and industry and the effects from the Kura River may have rendered the coast of Azerbaijan almost untenable for life (Bickham, 1996; Pohlman and Naismith, 1996; Rowe, 1996). Radioactive waste, both liquid and solid, was found in low lying depressions around nuclear power plants and was liable to enter the Caspian (Rodionov, 1994; Dumont, 1995).

On the plus side sturgeons, and presumably cyprinoids, may benefit from easier access to spawning grounds (*Ottawa Citizen*, 9 July 1994; 3 July 1995) but this is probably offset by the pollution load of the major spawning rivers.




Sea level rise in the Anzali Talab,
(GRID-Arendal, UNEP, www.grida.no/resources/5734,
Riccardo Pravettoni).

In contrast to the recent rise in sea level, a series of reports have appeared in past scientific and popular literature on the falling level of the Caspian Sea and diversionary schemes to combat this (e.g., Kovda, 1961; Lamb, 1977; Hollis, 1978; Gribbin, 1979; Micklin, 1979, 1986; Golden, 1982; Rich, 1982, 1983; Voropaev and Kosarev, 1982; Voropaev and Velikanov, 1985; Pearce, 1984; Ryan, 1986; Perera, 1989; Rozengurt and Hedgpeth, 1989; among others). The Caspian dropped 2.3 m between 1930 and 1962 and area had decreased by 10% or 40,000 sq km. Recent historical levels appear to be between -25 and -26 m, average -25.8 m. Fall in the sea level increased salinity, destroyed habitat and blocked spawning migrations, although some effects were less in the southern, Iranian Caspian because of the larger water mass. The Volga accounts for 76% (some reports say more than 80%) of the river input to the Caspian Sea. The Volga is now extensively dammed, as are other rivers in this basin, and its waters used for industry and agriculture. There are eight large dams on the Volga, the largest being the Kuybyshev with a reservoir area of 6,450 sq km and a total volume of 58 cu km. Dams in the Caspian basin provided almost one third of the hydropower of the former U.S.S.R. (Rozengurt and Hedgpeth, 1989). Flow into the Caspian has been cut by at least 25% and in spring, the time of spawning migrations, by as much as 37% for the Volga-Kama systems. Berka (1990) reviewed the effects of water level changes on the northern Caspian fisheries. The North Caspian was designated as an ecological disaster area in 1992 because of water pollution input from the Volga. The delta is eutrophic with cyanobacterial blooms being common, affecting fish survival (Saiko in Glantz and Zonn, 1997).

The decline in sea level reversed in the 1990s and a rise of nearly 2 m was reported and, in Turkmenistan, a shoreline advance of 2-3 km in places (Rich, 1991; Anonymous, 1992a;

Golub, 1992; *Ottawa Citizen*, 9 July 1994; *Priroda*, 5:3-25, 1994). This had positive effects for some fisheries and wetland conservation but negative effects on low-lying construction including oil refineries and wells in Azerbaijan and a nuclear waste dump in Turkmenistan which would cause massive pollution from oil and radioactive compounds (Pearce, 1995). Environmental hazards to the fisheries caused by sea level rise included eutrophication from farmland covered by the sea, pesticides and herbicides from inundated farmland, salt water penetration into wetlands, input of solid municipal and industrial wastes and vegetation, destruction of fish habitat, changes in groundwater level, erosion of barrier shorelines, sediment redistribution, and input of soil altering the ecosystem (Shayegan and Badakhshan in Glantz and Zonn, 1997; Filizadeh, 2010).

It has been suggested that the rise in sea level was due, in part, to seepage from the Aral Sea basin and that this could be halted by setting off underground explosions. This smacks of the large-scale alteration to the environment favoured by Soviet planners to combat the <u>fall</u> in sea level - both are grandiose and have unknown consequences for the environment. Climate change is probably a major factor abetted by the closing off of the Kara Bogaz Gol (responsible for an estimated 40-45 cm rise alone) and diversion of Siberian rivers into the Ural River in the northeastern Caspian (Khan *et al*., 1992).

Much of the former southern U.S.S.R. is water poor and a solution to this and the falling Caspian level has been advocated. This would involve diversion of north flowing Siberian rivers at a cost $40 billion. The potential for environmental damage on a local and even global scale caused this scheme to be shelved in 1986. The project involved excavations using nuclear explosives, drowning of forests and construction of canals thousands of kilometres long. Reduced flow into the Arctic Ocean could affect ice cover which influences atmospheric pressure and circulation patterns over the whole northern hemisphere. This Soviet plan was revived (Pearce, 2004) but not carried out.

There is an abundance of historical and other evidence for variations in Caspian Sea level and its connections with other water bodies in both recent times and over several million years (Huntington, 1907; Ehlers, 1971; Lamb, 1977; Gerasimov, 1978b; Hsü, 1978; Coad, 1980b; Rögl and Steininger, 1984; Wossugh-Zamani, 1991b; Oosterbroek and Arntzen, 1992; Sal’nikov, 1995; Mamedov, 1997; Rychagov, 1997; Caspian Environmental Programme, 2000; Grigorovich *et al*., 2003; Kotlík *et al*., 2008; Kakroodi *et al*., 2015; van Baak *et al*., 2019; Jorissen *et al*., 2020). Brooks (1949) maintained that the Oxus (= Amu Darya) flowed into the Caspian in the 14th century instead of the Aral Sea. Shnitnikov (1969) and Gerasimov (1978a) reported flow along the Uzboi channel north of the Iranian border into the Caspian from the Aral Sea basin at several periods from the third millennium B.C. to the 16th century. Sal'nikov (1998) illustrated connections between the Amu Darya and the Caspian Sea from the Pleistocene to the 20th century. The connection between the Caspian and Amu Darya and Aral Sea was interrupted about 20,000 years ago when the Amu Darya turned north, was reconnected about 10,000 years ago, and essentially interrupted about 4,000 years ago. These regular contacts have resulted in an Aral Sea ichthyofauna with weakly pronounced endemics, although the Amu Darya ichthyofauna has a number of clearly defined endemics which are not yet found in the Caspian Sea basin (but see below under Hari River basin). Dunin-Barkovsky (1977) recorded level fluctuations of up to 50 m during the Holocene due to variations in the general moistening of Eurasia and intermittent warming and cooling variously associated with changes in precipitation and evaporation. Ice melt from the Fennoscandian ice cap, as late as 4000 B.C., added large volumes of water to the Caspian and an overflow to the Black Sea was then possible. Berg (1948-1949) maintained that

*Atherina presbyter* (= *A. caspia*, Caspian silverside) and *Syngnathus caspius* (Caspian pipefish) entered the Caspian at about this time. Some fishes, such as *Salmo trutta* (as then recognised), were probably immigrants from Arctic regions and certain cyprinoids and percids were freshwater immigrants. Bianco (1990, 1995b) pointed out that, at every glacial-interglacial ice melting phase, a network of connected rivers and lakes allowed primary freshwater fishes to disperse in the northern Palaearctic. Other fishes are relicts of earlier transgressions. Such species as herrings (Clupeidae), gobies (Gobiidae) and possibly sturgeons (Acipenseridae) are believed to have evolved from the marine fauna of the Tethys Sea which ran from the modern Atlantic to the Indian Ocean before the Sarmatian basin formed. The uplift of eastern Anatolia and the Alborz in the Early Miocene between 20 and 17 million years ago (MYBP) closed a seaway from the Indo-Pacific which had extended into the Eastern Paratethys (= Black-Caspian-Aral Sea in modern terms). The connection reopened in the Middle Miocene 16.8-16 MYBP) but by the Late Miocene a Sarmatian basin was cut off from the open seas and developed a unique marine fauna (Ekman, 1953). This was mostly lost as salinity decreased from freshwater input and a new fauna developed. A series of connections and breaks with the Black Sea, Mediterranean Sea and the Atlantic Ocean in various combinations with brackish and freshwater episodes gave varying opportunities for faunal interchanges and evolution. The Caspian fauna differs from the Mediterranean one because its only communication was via the Black Sea which acted as a filter. When the Black and Caspian seas were well connected, the link to the Mediterranean was broken, and when the Black and Mediterranean seas were connected, the Caspian connection was not well-developed. Mamedov (1997) and Rychagov (1997) reviewed late Pleistocene and Holocene changes in Caspian Sea level, Chepalyga (1984) and Gerasimov (1978b) reviewed water level changes and connections with the Black Sea over the last 80,000 years, Kosarev and Yablonskaya (1994) and Mandych (1995) for the last 500,000 years and Grigorovich *et al*. (2003) for the last 12.5 million years. Krijgsman *et al*. (2019) reviewed in detail interbasin connectivity and faunal evolution for the Ponto-Caspian domain. They stated that Ponto-Caspian species are ones that evolved within the Black-Caspian seas basins in the past few million years under anomalohaline to freshwater conditions. Lineages typically go back into the Miocene Paratethyan basins while others only emerged in the Early Pleistocene. Bianco (1990) gave an overview of the palaeohistory of the Paratethys Basin, the present-day remnants of which are the Black and Caspian seas. Fluctuations in water level were correlated with climate changes. Kotlík *et al*. (2008) using multiple gene phylogeography found the Black and Caspian seas supported separate populations of *Rutilus frisii* during the last glaciation, although this separation was not complete and gene exchange occurred, with the majority of migrations in the Pleistocene. *Rutilus frisii kutum* was recognised as the Caspian subspecies but is now accorded species status.

Zoogeographically, Berg (1940) considered this part of Iran to belong to the Kura-Iranian sector of the Caspian District of the Ponto-Caspian-Aral Province. This fauna is very similar to that of the Kura River although certain genera are absent, even in the Sefid - a major river, such as *Chondrostoma*, *Gobio* and *Leucalburnus*.

An earlier, general work including fishes of the Iranian Caspian Sea and coast is Berg (1948-1949, in Russian but available translated into English). Fish lengths in Berg (1948-1949) are probably total length for illustrations (“natural length”) and probably so too for lengths given in the text unless body length (= standard length) is cited. More recent works are the atlas of the fish species in the Iranian Caspian Sea in English and Farsi by Naderi Jolodar and Abdoli (2004), that on the biodiversity of the southern basin by Abdoli and Naderi (2009), a checklist by

Esmaeili *et al*. (2014), and on fishes of Gilan by Abbasi Ranjbar (2017) (and see review and checklist by Radkhah *et al*. (2019).

The Caucasus Hotspot spans 500,000 sq km of Armenia, Azerbaijan and Georgia, as well as parts of Russia and Turkey, and encompassing part of the Caspian Sea basin of Iran. It has 127 species of fishes of which 12 are endemic (www.caucasus-naturefund.org/; Mittermeier *et al*., 2004).


Caucasus Hotspot
(CC BY-SA 4.0, ConservationIntl).

The commercially important species of fish were summarised in *Abzeeyan*, Tehran, 5(7):VII-IX (1995) and were divided into sturgeons (Acipenseridae, four species) and bony fishes (three species of kilkas in the genus *Clupeonella* of the family Clupeidae; herrings or *Alosa* spp. also in Clupeidae; five species of the former family Cyprinidae namely *Rutilus frisii* (= *R. kutum*), *Cyprinus carpio*, *Abramis brama*, *Rutilus rutilus* (= *R. lacustris*) and *Aspius* (= *Leuciscus*) *aspius*; two species of mullets, family Mugilidae, *Liza aurata* (= *Chelon auratus*, golden mullet) and *L. saliens* (= *Chelon saliens*, sharpnose mullet); a member of the perch family, Percidae, namely *Sander lucioperca* (pike-perch); and a member of the salmon family, Salmonidae, namely *Salmo trutta* (= *S. caspius*, Caspian trout). About 70% of *Rutilus kutum* were caught in Gilan Province, while 60% of mullets and 75% of sturgeons were caught in Mazandaran Province. Ivanov (2000) summarised the biological resources of the Caspian Sea from a Russian perspective with some comparative figures from Iran. Generally, catches in Iranian waters were always less than those in former Soviet Union countries combined. A particular exception was *Rutilus kutum* (sefid mahi), an esteemed fish in Iran.

About 25% of the Iranian total fish catch is from the Caspian coastal area and figures for

the Iranian Caspian Sea in tonnes are given below, showing the relative importance of non-cyprinoids:-

| Year | All fish species | Kilka (*Clupeonella* spp., Clupeidae) | Sturgeon flesh | Caviar |
|---|---|---|---|---|
| 1976/77 | 8,428 | 1,131 | 2,368 | 221 |
| 1981/82 | 10,466 | 1,341 | 1,914 | 234 |
| 1986/87 | 11,084 | 2,384 | 2,500 | 303 |
| 1991/92 | 34,596 | 13,817 | 2,208 | 283 |
| 1992/93 | 40,598 | 21,527 | 2,198 | 262 |
| 1993/94 | 52,768 | 28,730 | 1,170 | 217 |
| 1994/95 | 69,700 | 51,000 | 1,700 | 218 |
| 1995/96 | 58,300 | 41,000 | 1,500 | 182 |
| 1996/97 | 74,100 | 57,000 | 1,600 | 195 |
| 1997/98 | 76,200 | 60,400 | 1,300 | 151 |
| 1998/99 | 101,500 | 85,000 | 1,200 | 157 |

The fish harvest from the southern Caspian coast of Iran for the seven-month period October 1999-April 2000 dropped by 11% over the same period from the year before, from 8,630 t to 7,710 t (*Islamic Republic News Agency*, 10 May 2000). The decline was attributed to a rise in fish prices which encouraged illegal fishing, substandard fishing methods, and to habitat loss. Ghasemi and Kalteh (2015) investigated reasons for illegal fishing in Golestan and Mazandaran provinces of the Caspian Sea basin. Lack of rangers and deficient protective actions were important and recreational fishing was an incentive for illegal actions. Ahmad Mir Mohammad Tabar *et al*. (2021) found nearly 53% of respondents to a survey in Fereydun Kenar, Mazandaran engaged in illegal fishing.

Fallahi (2012) analysed the effects of aquaculture and stocking of native species in the Caspian Sea basin of Iran on fisheries development. It was recommended to utilise research held in fisheries research centers and by aquaculture experts, to activate veterinary organisations in production and post-production, and to add new brood stocks with desirable growth as the main strategies for developing Chinese carp culture. Preventing illegal fishing in the sea and rivers, preserving the population of Caspian Sea fishes, adding breeding and fingerling production for fish species whose resources are extremely decreased, and using bream, for example, while they migrate to Anzali Lagoon from the Caspian Sea instead of freshwater brood stocks, would help

enhance the output of sea fisheries and sea ranching activities.

The value for the whole Caspian fisheries was given as $6 billion by Nezami *et al*. (2000). A proposal for a Caspian Fisheries Commission was given by TACIS (1999, 2000b) and ERM-Lahmeyer International GmbH *et al*. (2001b). It would aim to conserve and utilise the living aquatic resources. Abdolmalaki (2014) performed a library-based study on fishing and resource management of bony fisheries in the southern Caspian Sea.

About 50,000 tonnes of kilkas (*Clupeonella* spp., Clupeidae) were caught each year by the Industrial Fishing Company and fishing cooperatives using deep conical nets and air lifting with artificial lights as attractants. About 20,000 t of other species were caught by licensed cooperatives using beach seines and gill nets although a report in the *Islamic Republic News Agency* (27 March 2000) cited more than 16,000 t including whitefish (*Rutilus*), Mugilidae, former Cyprinidae, anchovy (*sic*), bream (*Abramis*) and zander (*Sander*). An account of site selection for beach seining was given by Zanoosi (1993) and Gholamy *et al*. (2014) gave details of changes in substrate structure caused by beach seining. Khanipour (2009) reported on a standardised beach seine design which reduced the amount of premature or non-standard fish caught, from 67.1% to 7.1% for *Rutilus kutum*. Beach seining has been restricted to the period from sunrise to 8 p.m., and to 10 p.m. in Miankaleh (www.iranfisheries.net, downloaded 14 November 2006). The 1994-1995 finfish catch (excluding sturgeon and kilka) using gill nets, coastal purse seines and beach seines, was 17,000 t, perhaps over 22,000 t with the illegal catch included. About 87% of this catch was *Rutilus frisii kutum* (= *R. kutum*), *Liza aurata* (= *Chelon auratus*, golden mullet) and *Liza saliens* (= *Chelon saliens*, sharpnose mullet) (*Annual Report, 1994-1995, Iranian Fisheries Research and Training Organization, Tehran,* p. 37, 1996). Gill nets showed a 39% decline compared to the previous year and beach seines were 16% less. *Rutilus kutum* comprised 53%, mullets 39% and others 8% of the total catch (*Abzeeyan*, Tehran, 6(5, 6):IV, 1995). The catch in Golestan Province rose from 470 t in 2000 to 3,278 t in 2005, attributed to artificial propagation, restrictions on beach seining, training about closed seasons and beach seine standards, increased fishing effort, and a favourable climate (www.iranfisheries.net, downloaded 14 November 2006). Yulghi *et al*. (2011) found mean yearly profit to be 1,626,155-41,585,259 rials and payback period to be 0.14-2.42 years for beach seines in Golestan. Dad *et al*. (2013) also summarised the profitability and performance of the beach seine cooperatives in Golestan for 2009-2010. Nodehsharifi *et al*. (2018) assessed species density in beach seines in Golestan from 2006 to 2009. In the first two years of the study density was *Cyprinus carpio*>*Rutilus frisii* (= *R. kutum*)>*Rutilus rutilus* (= *R. lacustris*). *R. kutum* at 503,525 kg was the highest catch in 2008 and *R. lacustris* at 864 kg the lowest in 2007. Paighambari and Moradinasab (2012) gave catches per unit effort (CPUE) in the beach seine fisheries of Gilan for two zones as 72.5 and 83.35 kg for *Rutilus kutum*, 0.18 and 0.09 kg for *Cyprinus carpio*, 0.17 and 0.097 kg for *Vimba persa*, 0.07 and 0.04 kg for *Luciobarbus brachycephalus* (= *L. caspius*), 0.05 and 0.03 kg for *Rutilus caspicus* (= *R. lacustris*), 0.05 and 0.03 kg for *Alburnus chalcoides*, 0.02 and 0.03 for *Abramis brama*, and 0.01 and 0.03 kg for *Leuciscus aspius*. Total CPUE for the two zones was 109.8 and 167.4 kg and the average of the total catch during beach seining was about 135 kg, indicative that some beach seine cooperatives were uneconomical. Fazli (2016) studied bony fishes in the Iranian coastal waters of Caspian Sea in the years 2013-2014 and 2014-2015. The number of beach seines was 124 and 120 and their fishing efforts were 44,688 and 46,299 seines, respectively. The total catches (including illegal fishing) were 17,144.3 mt and 16,733.2 mt during 2013-2014 and 2014-2015, respectively. The highest proportion of the catch belonged to *Rutilus kutum* and golden grey mullet (golden mullet,

*Chelon auratus*) (94.4% and 89.5%, respectively) in the two fishing seasons mentioned above. Growth parameters of *Rutilus kutum* were estimated as K = 0.19/yr, $L_\infty$ = 61.3 cm and $t_0$ =-0.99/yr and for *Cyprinus carpio* were K = 0.14/yr, $L_\infty$ = 70.8 cm and $t_0$ = 0/yr. Based on catch-at-age data, in the years 2013-2014 and 2014-2015, the total biomass from the biomass-based cohort analysis, was estimated as 46,900 mt and 41,000 mt for *Rutilus kutum*. The reference points of $F_{0.1}$ and $F_{35\%}$ were 0.41/yr and 0.34/yr for *Rutilus kutum*. A similarity test indicated that coverage rates of different years were homologous and similar, but the coverage rates of different months, regions and periods were not similar. Also, there were significant differences in community composition of fishes in the catch of beach seines among three durations, three regions and seasons. During 1996-2000, the indicator species were *Rutilus rutilus* (= *R. lacustris*), *Vimba vimba* (= *V. persa*), *Chalcalburnus* (= *Alburnus*) *chalcoides*, *Aspius* (= *Leuciscus*) *aspius*, *Barbus* sp. (presumably a *Luciobarbus* sp), the Caspian trout *Salmo trutta caspius* (= *S. caspius*) and the European catfish *Silurus glanis*, in the years 2000-2005 shads (*Alosa* spp., Clupeidae), *Abramis brama* and the northern pike *Esox lucius*, and in the years 2005-2012 *Cyprinus carpio* and pike-perch *Stizostedion* (= *Sander*) *lucioperca*. Also, in the western region of the Caspian Sea the species/groups were *Vimba vimba*, *Chalcalburnus* (= *Alburnus*) *chalcoides*, *Aspius* (= *Leuciscus*) *aspius*, *Barbus* sp. (presumably a *Luciobarbus* sp.), *Abramis brama*, *Stizostedion* (= *Sander*) *lucioperca*, *Esox lucius* and *Silurus glanis*, in the middle region *Rutilus frisii kutum* (= *R. kutum*), shads and *Salmo trutta caspius* (= *S. caspius*) and in eastern region mullets (Mugilidae), *Rutilus rutilus* (= *R. lacustris*) and *Cyprinus carpio*. Based on available models, the allowable biological catch was estimated at 8,250-9,750 mt for *Rutilus kutum*. Fazli and Parafkandeh Haghighy (2016) examined beach seine catches in Iranian waters of the Caspian Sea from 1996 to 2012. Kutum (*Rutilus kutum*) and mullets comprised 56.78% and 31.81% of the total catch. There were significant differences in community composition between morning, afternoon and nighttime, between 1996-2000, 2000-2005 and 2005-2012, between west, middle and east regions, and between seasons. During 1996-2000, *Rutilus rutilus* (= *R. lacustris*), *Vimba vimba* (= *V. persa*), *Chalcalburnus* (= *Alburnus*) *chalcoides*, *Aspius* (= *Leuciscus*) *aspius*, *Barbus* sp. (presumably a *Luciobarbus* sp.), *Salmo trutta caspius* (= *S. caspius*), *Silurus glanis*, in the years 2000-2005 species/groups shads, *Abramis brama* and *Esox lucius* (northern pike), and in the years 2005-2012 *Cyprinus carpio* and *Stizostedion* (= *Sander*) *lucioperca* were indicator species. In the west region species/groups *V. persa*, *A. chalcoides*, *L. aspius*, *Barbus* sp., *A. brama*, *S. lucioperca*, *E. lucius* and *S. glanis*, in the middle region *Rutilus kutum*, shads and *S. caspius*, and in the east region species/groups mullets, *R. lacustris* and *Cyprinus carpio* were identified as indicator species.

Caspian Sea, early 1960s, beach seining, Vadim D. Vladykov.

Gilan, Bandar Anzali, Caspian Sea, beach seining, 24 October 1974, Neil B. Armantrout.

Mazandaran, beach seining east of Amir Abad Port
(Amirabad Port 20150106 22, CC BY 4.0, cropped, Mehr News Agency,
Amir Ali Razzaghi).

Mirzajani *et al*. (2016) examined demersal and pelagic bony fish distribution and abundance in the southwest Caspian Sea. Unusually, certain freshwater cyprinoids were found. Pelagic cyprinoid fishes such as *Alburnus hohenackeri*, *Pseudorasbora parva* and *Hemiculter leucisculus* had limited distributions and demersal cyprinoids such as *Capoeta capoeta* (= *C. razii*) and *Abramis brama* had a very limited distribution with very low abundance. Demersal *Rutilus caspicus* (= *R. lacustris*) dominated in Hashtpar, Shafarud and Jafrud and demersal *Rutilus kutum* in Anzali. *Rutilus kutum* was the third most dominant demersal species at 10.3 fish/100 sq m (biomass 32.2 g/100 sq m) and *R. caspicus* (= *R. lacustris*) was at 8.0 fish/100 sq m (biomass 11.9 g/100 sq m) and *Vimba persa* at 3.9 fish/100 sq m (biomass 7.5 g/100 sq m). *Alburnus chalcoides* was the third most dominant pelagic species at 2.9 fish/100 sq m (biomass 5.3 g/100 sq m) followed by *Hemiculter leucisculus* at 1.1 fish/100 sq m (biomass 19.3 g/100 sq m). The dominance of *Rutilus* species was from restocking activities and from their natural breeding in the vicinity of big rivers. *R. kutum* comprised 68.7% (2,900 tons) of the total catch of bony fishes in this study area. *Luciobarbus capito* and *Aspius* (= *Leuciscus*) *aspius* had compositions of 0.03% and 0.09%, and their average annual abundance for the whole southern Caspian Sea was 7 tons and 2 tons. They were regarded as critically endangered. *Cyprinus carpio* had a mean fisheries percentage of 1.2% (20.1 tons) in 2012-2013 and a maximum fisheries percentage in 2002-2012 of 9.4%. This species occupied the third rank of the total harvest with an average of 1.7 thousand tons per year, with 97.5% of the total catch in the southeast Caspian Sea where restocking was implemented - hence the low harvest in the southwest Caspian Sea of Iran.

Vahabnezhad (2017) examined marine food web dynamics of small-sized pelagic fish in Iranian waters. Twenty-five species were used in the analysis based on the data collected from the kilka (*Clupeonella* spp., Clupeidae) fisheries, beach seining of bony fishes, set gillnets for sturgeon, and also dietary information. Total landings along the Iranian portion of the southern Caspian coast reached 39,647 t, including sturgeon (41 t), kilka (22,873 t) and bony fishes (16,733 t) in 2014. Two species of kilka (common and anchovy kilka) were important

commercially in the Caspian Sea, together accounting in the past decade for >60% of the total catch, as well as being a crucial part of the food chain. The mean average trophic level was estimated at 3.17 by Ecopath software. In this research, the mean levels were studied between eight species varied from 2.56 to 4.04, the percid *Sander lucioperca* occupied the highest and bream *Vimba vimba* (= *V. persa*) the lowest level. The ranges of total mortality varied from 0.5 to 2.56 per year. The food consumption rate was estimated about 101.56 per year. The mixed trophic level index showed small pelagic fishes as prey, having a crucial role in feeding of pelagic predator populations such as the invasive ctenophore *Mnemiopsis leidyi*, bream fish and benthic fish such as sturgeon. In general, niche overlap was greater in such species as *Alburnus chalcoides*, *Rutilus rutilus* (= *R. lacustris*), *Clupeonella cultriventris* (= *C. caspia*), *Rutilus kutum* and *M. leidyi*, which consumed large amounts of plankton. Small pelagic fishes exerted a major control on the trophic dynamics of the Caspian Sea ecosystem and constituted mid-trophic level populations.

Hashemi *et al*. (2019) studied the impact of fishing in the Iranian part of the Caspian Sea during 1991-2017. They found the mean trophic level was 2.91; the value initially was reduced, then increased and ultimately stayed constant. The mean fishing-in-balance was 0.13 and its trend was similar to total landings. The mean piscivory index, ratio of pelagic and demersal landings index, and pelagic fish and demersal fish were 0.04, 3.16, 38,529 t and 13,380 t respectively. These results revealed that stocks were over-exploited. The main cyprinoid species involved were *Abramis brama*, *Alburnus chalcoides*, *Carassius carassius* (probably *C. auratus*), *Cyprinus carpio*, *Leuciscus aspius*, *Luciobarbus capito*, *Rutilus kutum*, *Rutilus persicus* (*sic*, presumably *R. lacustris*) and *Vimba persa*, all classified as demersal except the pelagic *A. chalcoides* and *L. aspius*. The average landing, percentage of landing and cumulative percentage of landing for the 1991-2017 period were 10,249.5 kg, 19.7% and 85.6% for *Rutilus kutum* and 1,544.3 kg, 3.0% and 95.8% for *Cyprinus carpio* for example.

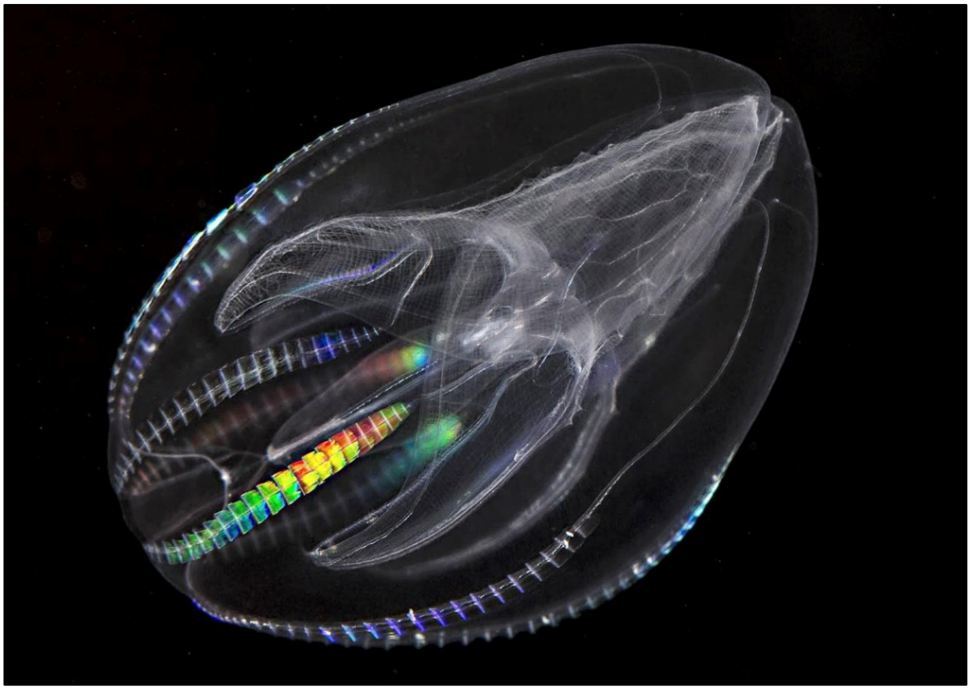
There are five regional fishing centres namely Bandar-e Anzali with 14 fishing stations, Keyashahr with 12 stations, Babol Sar with 13, Ashuradeh with nine and Nowshahr with nine (*Iranian Fisheries Research and Training Organization Newsletter*, 7:7, 1995). A 1995 agreement between Iran, Azerbaijan, Turkmenistan, Kazakhstan and Russia gave each nation an exclusive fishing zone of 20 nautical miles from shore (*Iranian Fisheries Research and Training Organization Newsletter*, 7:7, 1995).

Inland freshwaters of Gilan are divided into three categories by Bakhshizod-Mahmoodi (1996):- natural and impounded ponds, the Sefid River Dam or reservoir, and wetlands. The ponds were used primarily for cyprinoid and acipenserid culture, the reservoir was fished by seining, by spreading wheat grains in littoral areas to attract fish and by using the *shemshad* or *shaghoul* net (a giant dip-net, see above under **Methods**), and the wetlands were fished by seining, by the *salik* or *mashak* (cast-nets), by the *la'kesh* (drifting gill net using one and two boats), by fixed gill nets, by the *shemshad* and by angling (for ordak mahi or northern pike, *Esox lucius*).

Gilan, fishing nets at Bandar Anzali, 1924-1925
(CC0, cropped and sharpened, ETH-Bibliothek, Walter Mittelholzer).

The use of waste fish oil from the Caspian Sea fisheries as a biodiesel has been investigated by Yahyaee *et al*. (2013).

The Caspian Sea fisheries were predicted to collapse when the 10 cm long ctenophore or comb jelly *Mnemiopsis leidyi* from the northwestern Atlantic Ocean entered the Caspian Sea via the Volga-Don canal in ballast water. It reached the Black Sea in the early 1980s and destroyed the local pelagic food chain (Travis, 1993; Dumont, 1995; Pearce, 1995; GESAMP, Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, 1997; Negarestan *et al*., 2002; Kideys, 2002a, 2002b, 2003). The ctenophore eats fish eggs and larvae directly as well as zooplankton and crustaceans which are foods for fish (Bagheri *et al*., 2005). The Black Sea fish catches fell 90% in six years and the biomass of the ctenophore reached an estimated 900 million tonnes, 10 times the world annual fish catch (or 1 billion t, about equal to the world fish catch - sources differ). The wet weight biomass of the whole Black Sea at times was 95% ctenophore. A continuing series of reports, magazine articles and studies on this invader are not all cited here.



*Mnemiopsis leidyi* (CC0, Stefan Siebert).

The earliest report for the Caspian appears to be in 1995 by the Iranian Fisheries Research Organization (Bilio and Niermann, 2004; www.caspianenvironment.org/mnemiopsis/mnem_attach13.htm). The *Islamic Republic News Agency* on 12 May 1998 reported that a number of jellyfish had been observed in the Caspian Sea recently, presumably brought in the ballast of oil tankers, and its occurrence was documented by Esmaili Sari *et al*. (1999) and in other studies by this author and co-authors. Various studies on the biology of the comb jelly and its impacts have been carried out in the Iranian Caspian Sea including, e.g., Movahedinia *et al*. (2002), Esmaeili *et al*. (2003), Yussefian (2002), Moghim and Rouhi (2009), Bagheri *et al*. (2010), Fazli (2011), Ghodrati Shojaei *et al*. (2012), Dadgar and Owfi (2015), Eslami *et al*. (2015), Pourang *et al*. (2016) and Fazli (2017), among others.

The kilka (*Clupeonella* spp., Clupeidae) fisheries were threatened by the comb jelly which spread through the entire sea by the year 2000. J. Muir (http://news.bbc.co.uk/hi/english/world/middle_east/newsid_1453000/1453117.stm, downloaded 30 August 2001), Kideys (2002b) and Kideys and Moghim (2003) reported a 50% drop in kilka numbers with catches down from 3-6 t per night to half a tonne for one boat. A 50% decrease in kilka catches meant a minimum U.S. $15 million loss to the fishermen (Kideys and Moghim, 2003). Iran's kilka fishery fell from 85,000 t in 1999 to 15,000 t in 2004 and losses exceed $125 million (Stone, 2005). Ghafar Zadeh and Honar Bakhsh (2008) summarised the economic consequences for Iran. Fazli (2017) however noted that the average catches of bony fishes (including cyprinoids) over three periods (1996-2000, 2001-2006 and 2007-2011, representing establishment, expansion and adjustment) were not significantly different while kilka and sturgeon catches declined sharply. This comb jelly can double in size in one day, reaches maturity in two weeks and then produces 8,000 young every day. Maximum abundance reached 5,122 individuals per square metre in October 2001 and biomass 1,024.5 g/sq m in August-October 2002 (Roohi *et al*., 2003; Bagheri, 2004, 2006). Bagheri *et al*. (2012) gave figures of ca.

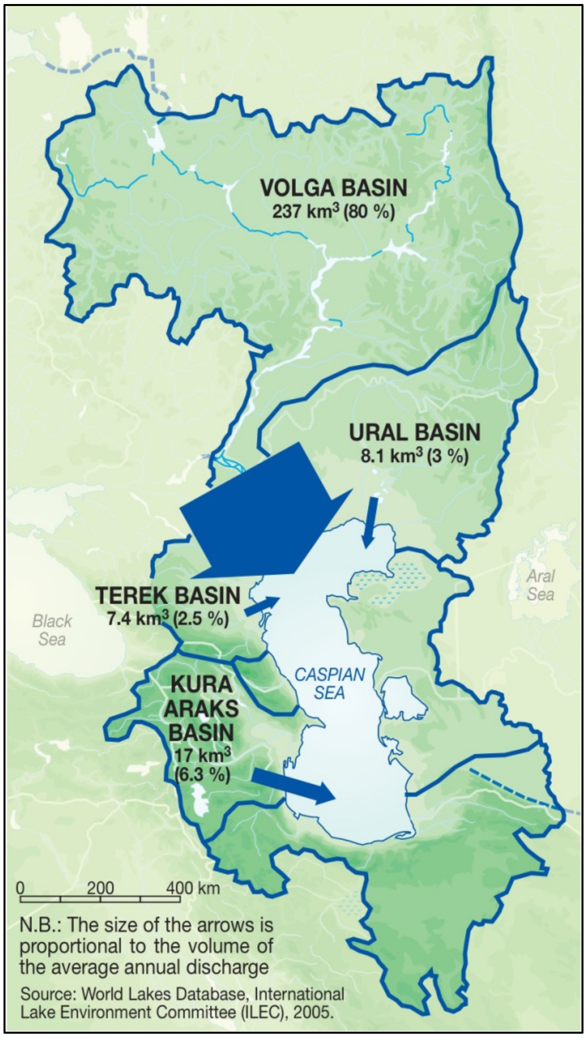
200 individuals/cu m (2,000 individuals/sq m) and 16 g wet weight/cu m (180 g/sq m), in the same range as previous surveys for Iranian waters. The fisheries may recover somewhat after the comb jelly population collapses (Tidwell, 2001b). The website www.caspianenvironment.org, downloaded 9 April 2003 and Dumont (2002) have extensive information on this problem and Stone (2002) and *Iranian Fisheries Research Organization Newsletter* (29:4, 2001; 65:4, 2011) confirmed a severe depression in kilka (*Clupeonella* spp., Clupeidae) and herring (*Alosa* spp., Clupeidae) stocks. *Beroe ovata*, a comb jelly that preys on *Mnemiopsis*, was being cultured in Iran (Kideys, 2002b; Kideys *et al*., 2004; Rezvani Gilkolaei *et al*., 2005; Mirzajani, 2006; Mirzajani *et al*., 2007) and did not appear to feed on other organisms in the Iranian Caspian (*Iranian Fisheries Research Organization Newsletter*, 38:3, 2004). Reproduction and growth are slower, and mortality higher, than in the Black Sea, due either to the lower salinity in the Caspian Sea water or damage to individuals during transportation for the experiments. If this comb jelly fails to control *Mnemiopsis*, the introduction of the exotic American species, the butterfish (*Peprilus triacanthus*) known to feed on ctenophores, has been advocated but this fish could also feed on other fishes (Harbison, 2002; Bilio and Niermann, 2004). The complex politics of the nations surrounding the Caspian have prevented the introduction of *Beroe* (Stone, 2005).

Habitat destruction has severely impacted fish populations. The area of forests in northern Iran was reduced from 3.4 million hectares in 1962 to 1.8 million hectares in 1977 and about 1 million hectares or less in 1995. In Gilan, 975,000 cu m of wood from the forests were burnt annually by cattle breeders for heating or cooking purposes or for production of dairy products. Additionally, 450,000 cu m of wood was used for industrial purposes. Reforestation cannot keep up with the losses and forests have been reduced by half over the past 50 years (Barzegar, The Agricultural and Cattle Breeding Publication, No. 761, 22 December 1997, from www.netiran.com/Htdocs/Clippings/Deconomy/971222XXDE01.html). As a result, floods now occur with destruction of fish habitat after 30-40 hours of rain where previously no flooding occurred after even four days of rain (*Hamshahri*, Tehran, 628, 20 February 1995). Abstraction of water for irrigation (60% of water use) severely reduced water levels and runoff rates necessary for reproduction of fishes. Estuarine habitats were degraded inhibiting the survival of eggs, larvae and juveniles of anadromous and semi-anadromous fishes (the latter are species which spawn in the lower stretches and deltas of rivers where salinity is optimal at 8 g/l for many commercial species, e.g., *Sander lucioperca* (pike-perch), *Cyprinus carpio*, *Rutilus caspicus* (= *R. lacustris*)). Over 90% of coastal streams along the Caspian shore are dry in July in Iran because of irrigation demands. As a result, larvae of spring spawners are flushed into fields where they die, migration and late summer spawning of *Aspius* (= *Leuciscus*) *aspius* and *Luciobarbus brachycephalus* (= *L. caspius*) are obstructed, and *Salmo caspius* (Caspian trout) and *Rutilus frisii kutum* (= *R. kutum*) populations are depleted because they cannot spawn in the shallow, warm, weed-choked water. Nursery and reproductive areas for *Abramis brama*, *A. sapa* (= *Ballerus sapa*), *Blicca bjoerkna*, *Aspius* (= *Leuciscus*) *aspius*, and *Sander lucioperca* among others are confined because of their low tolerance to salinities above 7-8‰. Without an adequate runoff, the sea encroaches on the estuary. Nasri-Chaari (1994) cited physical obstacles, sand removal from river banks, overfishing and water pollution for declines in fish migration in recent years. Gholami (2021) briefly mentioned sand mines and river blockages as serious threats to fishes.

Pollution is an important factor in the ecology of the sea, from offshore oil drilling, ship discharges of oil wastes and contaminated water, as well as garbage and even discharges from ship collisions, radiation from underground, non-military explosions and nuclear waste dumped

in inflowing rivers (radiation levels are 100 times above normal (*Time*, 1 November 1993)), manure and pesticides from farming on the surrounding land mass, city wastewater, sewage and garbage, industrial wastes including mercury and other heavy metals, discharges from water desalinating plants, extraction of minerals such as sodium sulphate, mirabelite and espomite, and untreated sewage (see Sardar (1979), Coad (1980b), Nuhi and Khorasani (1981), Khalili (1994), Raiss-Tousi (1999), Namazi (2000), Abaee (2001), Charamlambous (2001), Laloei (2006), Ghane Sasansaraie (2007), Hashemian Kafshgari (2009), Zeynali (2009), Saeidi *et al*. (2010), Tabari *et al*. (2010) Okati *et al*. (2012), Obadi *et al*. (2019) and Mirzajani *et al*. (2020) for Iranian problems and acceptable levels of some elements; Anonymous (1988b), Edwards (1994), Specter (1994) and Kasymov and Rogers (1996) for former Soviet waters; Stone (2002) is a recent, short general overview). However, discharge from the Iranian coast is relatively minor - see below.

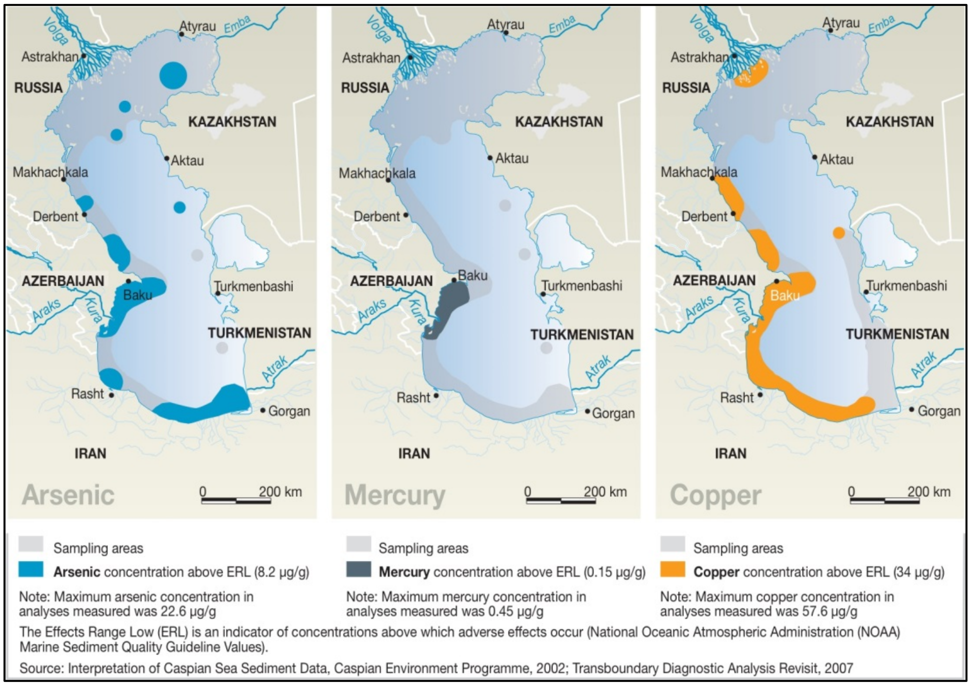
Gilan, fish killed by depth charges used in Iran-Russia oil exploration,
beach north of Bandar Anzali, 4 August 1967, Neil B. Armantrout.



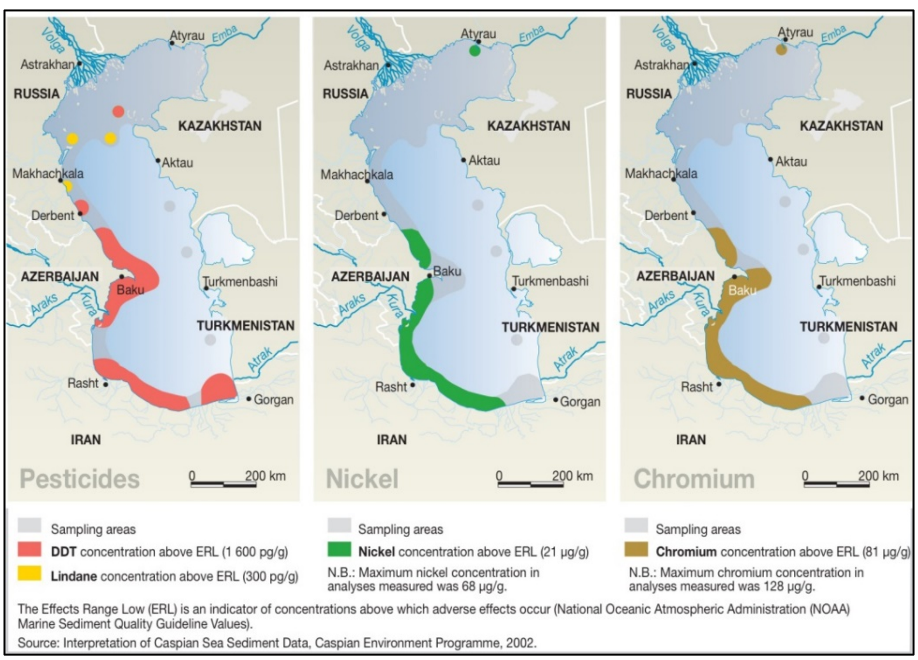

Caspian Sea annual discharge
(Philippe Rekacewicz (le Monde Diplomatique)
assisted by Laura Margueritte and Cecile Marin,
later updated by Riccardo Pravettoni (GRID-Arendal),
Novikov, Viktor (Zoi Environment Network),
www.grida.no/resources/5734, UNEP).

Data collected in 1991 showed the Caspian Sea received effluents comprised of 3,000 tonnes of oil products, 28,000 t of sulphites, 315,000 t of chlorides, 200,000 t of tar and 25,000 t of phenols (Namazi, 2000). In Dagestani rivers, the same author recorded heavy metals, pesticides, phenol, arsenic, boron and selenium, among others, at 60-100 times the maximum permissible for fisheries. The oil industry was considered to be the main source of ecological problems in the Caspian Sea (Karpyuk, M. and Shavandin, V. 1996. Astrakhaners on the Caspian Sea. International Affairs, 42(1) from http://home.eastview.com/ia/42_01_15.htm). Prospecting used blasting operations which caused sturgeon deaths on more than one occasion, and presumably cyprinoids. A single offshore well during its life released into the water 30-120 tonnes of oil, 200-1,000 t of sand, clay and other waste and 150-400 t of drilling mud, paraffin fractions, baryta, lime, detergents, emulsifiers and lubricants. The ecology was affected 5-12 km

from each well. The oil industry in the Caspian had reserves estimated at $4 trillion and a new oil rush would further contaminate the sea.



Caspian Sea heavy metals
(Philippe Rekacewicz (le Monde Diplomatique) assisted by Laura Margueritte and Cecile Marin, later updated by Riccardo Pravettoni (GRID-Arendal), Novikov, Viktor (Zoi Environment Network), www.grida.no/resources/5734, UNEP).



Caspian Sea pesticides and heavy metals
(Philippe Rekacewicz (le Monde Diplomatique) assisted by Laura Margueritte and Cecile Marin, later updated by Riccardo Pravettoni (GRID-Arendal), Novikov, Viktor (Zoi Environment Network), www.grida.no/resources/5734, UNEP).

Charamlambous (2001) concluded that municipal wastewater from 11 million people was the primary pollutant in Iranian coastal waters. Industrial discharge accounted for 31% of organic loading, the rest being municipal discharge. The most industrialised area was around Rasht with waste going into the Anzali Talab. The Zarjub River in Rasht was the most polluted river in Gilan, and possibly in Iran (Ghodrati *et al*., 2007). However, Ebadi Fathabad *et al*. (2018) reported levels of arsenic, cadmium, chromium, lead, mercury, nickel and tin from fish at the Rasht Fish Market and all were acceptable for human consumption with whitefish (*Rutilus kutum*) having the highest levels of four fish species examined for arsenic, lead, mercury, nickel and tin. TACIS (2000c) reported that in Gilan, 32 of 36 major cities discharged wastewater untreated into a river and 89 of 90 industries discharged treated wastewater to a river. Ayati (2003) also reviewed pollution in the Anzali Talab. Mirkou (2001) detailed agro-chemical usage along the Caspian shore comprising various fertilisers and pesticides. Naderi Jeloudar *et al*. (2007), Varedi *et al*. (2007), Amirkolaie (2008), Naderi Jolodar *et al*. (2011), Sarkhosh *et al*. (2015a, 2015b, 2017), Tavakol *et al*. (2017) and Nabavi *et al*. (2020) described the environmental impact on the Haraz River of aquaculture wastewater discharge from *Oncorhynchus mykiss* (rainbow trout) farms. Pollution levels in this instance were generally too low to have a significant impact on the river system as a whole although phosphorus loading was increased, levels were high near farms, and levels varied with activity rates of the farms. Eutrophy and polysaproby (rich in decomposable organic matter and nearly free from dissolved oxygen) were increasing as some fish farms were being built too close together. A reliable distance for self-purification of the river was 2 km. Benthic macroinvertebrates also showed evidence of pollution being high near trout farm effluents, clearing about 3.5 km downstream. Ghane Sasansaraie (2007) examined pollution in the Hevigh, Karkan and Shafa rivers and found an overall reasonable quality, but some signs of destruction and degradation such as sedimentation, relative increase of nutrients and increased concentrations of some pollutants, all of which resulted in the low diversity of macroinvertebrates and prevented migration of anadromous fishes. Hashemian Kafshgari (2009) sampled eight lines from Astara in the west to Gomishan in the east in lower than 10 m depths. Average physical factors such as pH were 8.11, salinity 12.12 p.p.t. and dissolved oxygen 6.7 mg/l. Average chemical factors such as $NO^2$, $NO^3$ and $NH^4$ were 1.2 µg/l, 25.7 µg/l and 13.0 µg/l, respectively. Total nitrogen, organic nitrogen and inorganic nitrogen were 690.2 µg/l, 667.6 µg/l and 41.6 µg/l. Average silicate was recorded at 266.35 µg/l. Total phosphorus was 37.35 µg/l and average organic phosphorus was 20.25 µg/l. The average total organic matter was 4.98% and the maximum amount was observed at Lisar and the minimum at Nowshahr. The concentration of heavy metals during sampling were, respectively, Fe>Mn>Zn>Cr>Ph>Co>Cd>Cu. The maximum concentration of Fe was in winter in Nowshahr and Babolsar respectively at 13.3 µg/l and 17.1 µg/l. In many stations and different seasons, the amount of heavy metals was at a lower standard for marine waters. The concentration of polycyclic aromatic hydrocarbons (PAHs) in autumn was 0.13 p.p.b. and in winter was 0.12 p.p.b. The amount of PAHs in the southern Caspian Sea was lower than in other parts of the Caspian Sea. The average of detergent concentration (linear alkylbenzene sulfonates) was 0.036 µg/l that was two-fold higher than the level determined in 2001. The maximum density of phytoplankton was observed in autumn and the minimum in winter. A total 19 species of zooplankton were identified. Maximum diversity was observed in summer and a minimum in winter. Zooplankton changes during sampling showed the density of zooplankton in 5 m depths was more than in 10 m depths. A total of 17 species of macrobenthos were identified. The composition of macrobenthos groups was respectively, Annelida (92.7%), Bivalvia (2.7%)

Gammaridae (108%, *sic*), Cumacea (1.5%) and Balanidae (103%, *sic*). Maximum density was observed in Astara and the minimum density in the Sefid River. Average density was 1,218 individuals/sq m. A higher density was recorded in autumn and a lower density in winter. The correlation of phytoplankton and zooplankton with physicochemical parameters and also the relation between total organic matter and sediment grain size was calculated. Ecological indices were calculated for the macrobenthos. Data showed the impact of the ctenophore (*Mnemiopsis leidyi*) on zooplankton, phytoplankton and macrobenthos density. Khosropanah *et al*. (2011) measured variations in nitrate and phosphate levels in the sea from Astara to Chaboksar, noting increasing trends in concentrations probably caused by discharge of untreated domestic sewage and pesticides from agriculture in rivers along the coast. Imanpour Namin *et al*. (2013) found significant differences in water quality above and below fish farms in the Tajan River and diversity of macroinvertebrates varied significantly above and below the farms. Aazami *et al*. (2015, 2015a) found a decrease in downstream water quality in the Tajan River from pulping and papermaking operations or sand mining, and these had more effects than agriculture and fish ponds in the upstream part. Mazaheri Kohanestani *et al*. (2013) also documented the effects of trout effluents in the Zarrin Gol Stream, Golestan.

Golestan, Zarrin Gol Stream, Gorgan River basin, Hamid Reza Esmaeili.

Noorbakhsh *et al*. (2014) evaluated water quality in the Babol, Haraz and Siah rivers finding the best water quality in the upstream Haraz and the worst in the downstream Siah River. The condition of these Mazandaran rivers was unsuitable from the population load and excess urban activity, industry, chemical fertilisers and pesticides, discharge of rural, urban and industrial wastewater and solid wastes, and water abstraction for agriculture and industry. Behmanesh (2020) evaluated water quality in the Babol River and it was found to be suitable for fish farming in terms of pH, temperature and total dissolved solids but was unsuitable for dissolved oxygen, water turbidity and heavy metal load.

Chlorinated pesticides have been used in antimalarial campaigns and to eliminate pests on cotton, rice and other products in Mazandaran. Herbicides and pesticides are widely used in

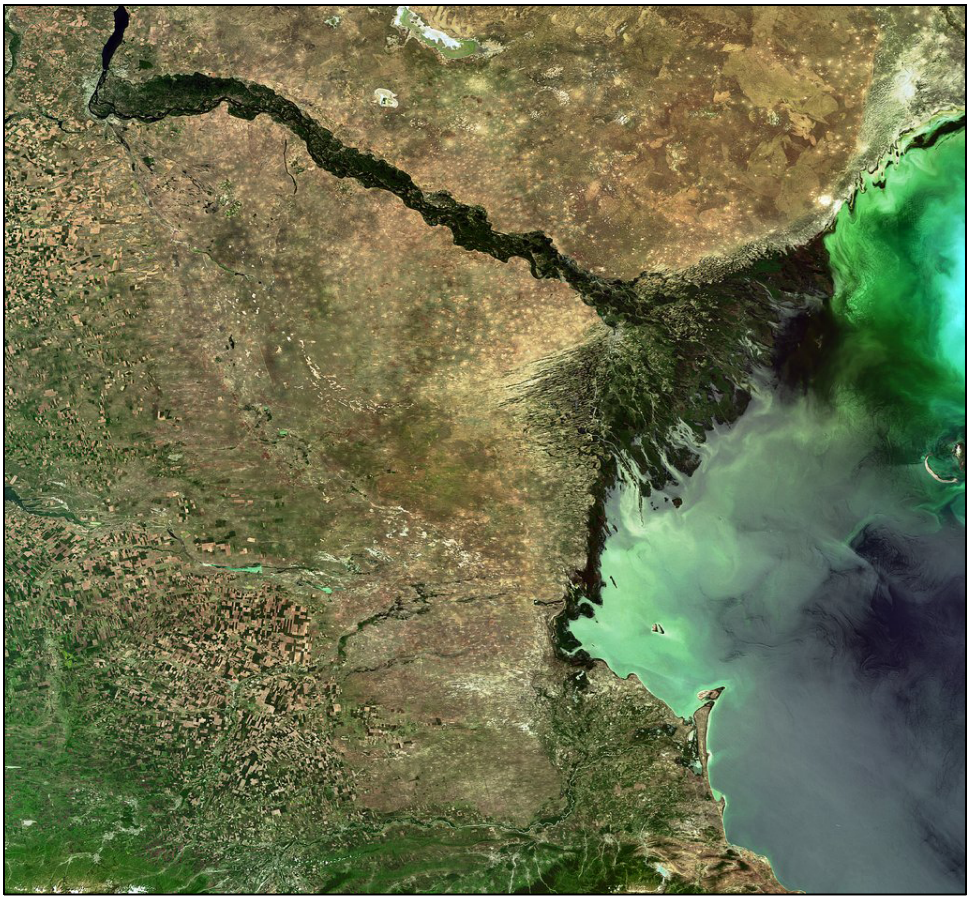
rice paddies. Alderin, DDD, DDE, DDT, diazinon, dieldrin, eindrin, endosulfan, heptachlor, kelthane, lindane, malathion, metoxychlor and others have been identified in such rivers as the Babol, Chalus and Sardab, often above allowable limits (*Annual Report*, *1995-1996, Iranian Fisheries Research and Training Organization, Tehran,* pp. 11-13, 1997; Behtash *et al*., 2011; Fadaei *et al*., 2012). Ebadi and Shokrzadeh (2006) examined *Rutilus frisii* (= *R. kutum*), *Vimba vimba* (= *V. persa*), the clupeid *Clupeonella delicatula* (= *C. caspia*, common kilka) and *Liza aurata* (= *Chelon auratus*, golden mullet) for the pesticide lindane at Babol Sar, Chalus, Khazarabad and Miankaleh but levels detected were less than the FAO/WHO recommended permissible intake and were no cause for public concern. Similar studies on DDE and DDT and on chlorobenzilate from the same sites and fish found levels were also less than the permissible intake (Shokrzadeh and Ebadi, 2005, 2006). Shokrazadeh *et al*. (2009) also found that levels of lindane in dorsal muscle of sefid mahi (*Rutilus kutum*), kefal (mullets), kuli (*sic*, probably an *Alburnus* sp.) and kilka (Clupeidae, *Clupeonella*) species were less than FAO/WHO recommended intake. The Chalus River also contains various heavy metals, such as cadmium, chromium, copper, iron, lead and zinc from mining activities (*Annual Report, 1995-1996, Iranian Fisheries Research and Training Organization, Tehran,* p. 18, 1997). Reyhani *et al*. (2013) found upstream stations in the Sardab River contained heavy metals but these were from natural sources and pollution was very weak and within acceptable limits except for copper. Zeynali *et al*. (2009) demonstrated the presence of copper and zinc in muscle tissues of *Liza aurata* (= *Chelon auratus*, golden mullet), *Cyprinus carpio* and *Rutilus frisii kutum* (= *R. kutum*) from Anzali, Chalus, Fereydun Kenar and Rudsar although levels were acceptable for human consumption. Hashemy-Tonkabony and Asadi Langaroodi (1976) showed the presence of aldrin, DDE, DDT, TDE, dieldrin, heptachlor and lindane in a wide variety of Caspian fishes in Iran. However, Ebadi and Shokrzadeh (2006) examined *Alburnus*, *Rutilus frisii* (= *R. kutum*), *Clupeonella* (kilkas, Clupeidae) and *Liza* (= *Chelon*) species in Mazandaran for the pesticide lindane and found levels in muscle tissues to be less than Food and Agriculture Organization and World Health Organization recommended permissible intake and so were not a public concern. *Cyprinus carpio*, *Rutilus frisii* (= *R. kutum*), *Liza* (= *Chelon*) species and the sturgeon *Acipenser stellatus* were tested for DDT, aldrin and heptachlor with only the latter slightly elevated above standard levels at Hashtpar (*Iran Daily*, 11 January 2006).

Pollution caused phytoplankton diversity in the western Caspian Sea to fall from 74 to 40 species, biomass from 8.7 to 2.1 g/sq m and biomass of benthic organisms in coastal areas fell from 1,724 g/sq m in 1961 to 21 g/sq m in 1969 (Clark, 1986). These declines were noted particularly in the nursery grounds for sturgeon, *Abramis brama*, *Esox lucius* (northern pike) and *Cyprinus carpio* among other fish species. In the 1980s, catches of *Abramis brama*, *Cyprinus carpio*, *Rutilus rutilus* (= *R. lacustris*) and *Sander lucioperca* (pike-perch) fell by as much as 80% and *Salmo trutta* (= *S. caspius*, Caspian trout) and “shad” had almost disappeared.

It was estimated that for 1985, 10,200 tonnes of oil products and 104,200 t of sewage were dumped in the sea. One-fourth (or 40 billion cubic metres) of all the wastewater in Russia entered the Caspian Sea and petrochemical factories alone released 67,000 t of waste annually (Anonymous, 1988b; Platt, 1995; *Hamshahri*, Tehran, 3 (639), 7 March 1995). Salinity increased as more water was taken for irrigation - two-thirds of the Terek and Kura flows did not reach the sea (Markham, 1989). In Iran, sewage was discharged into the Caspian Sea from coastal towns, and via rivers, from towns inland. Industrial solid wastes entered the sea through the larger rivers such as the Sefid, Gohar and Siah as well as the Anzali Talab complex. The use of agricultural chemicals such as fertilisers and pesticides led to pollution, e.g., in Gilan Province 88,851 t of fertilisers were used in the year 1992-1993, an 18.7% increase over the previous year. A survey of 30 towns in Gilan showed that 80% of rubbish dumps were located by rivers, marshes or the coast (*Hamshahri*, Tehran, 3 (639), 7 March 1995). An estimated 200,000 fish were killed in the Kacha River, a branch of the Siyarud (= Siah) in Rasht, poisoned from a dump in the Saravan region which received 390 t of rubbish daily. Heavy rains washed poison into the river (*Tehran Times*, 7 October 1998). As many as 1,000 trout (presumably mahi azad or Caspian trout, *Salmo caspius*) died in the Cheshmeh Kileh (= Tonekabon) River in Mazandaran from release of wastes from a dairy manufacturer; sand extraction was also blamed for affecting fish populations, and presumably cyprinoids were affected too (*Iran Daily*, 21 July 2005). Shayeghi *et al*. (2001) studied residues of phosphorus insecticides in Mazandaran rivers finding variations in amounts with type of insecticide and method of application, time, and environmental conditions such as temperature, pH and rainfall. Ebadi Fathabad *et al*. (2020, 2020) compared dioxin-like polychlorinated biphenyls from five coastal cities of the Iranian Caspian Sea and found the total maximum concentration was in *Cyprinus carpio* from Bandar Anzali and the minimum was in *Vimba vimba* (= *V. persa*) from Chalus. The non-carcinogenic risk of exposure was at a safe level but the lifetime cancer risk estimated for Bandar Anzali, Bandar-e Torkeman and Rasht exceeded the threshold value suggested by U. S. Environmental Protection Agency. Golshani *et al*. (2020) studied the distribution and accumulation of diazinon, malathion and azinofos methyl in *Liza aurata* (= *Chelon auratus*, golden mullet), *Cyprinus carpio* and *Rutilus frisii kutum* (= *R. kutum*) from five estuaries along the Iranian Caspian Sea shore, namely the Babol, Chalus, Gorgan, Sefid and Tajan. Pesticide concentrations varied with fish species, sampling station pollution levels and toxins types. The order of toxin concentration was azinfos methyl>diazinon>malathion. There were significant differences in toxin concentrations between the three fish species. The highest concentrations were absorbed in a detritivore (*C. auratus*), followed by a herbivore (*C. carpio*) and a carnivore fish (*R. kutum*). The results confirmed that toxin bioaccumulation in these fish species was strongly controlled by habitat and feeding habits.

Abadi *et al*. (2017) found more than 58% of the 36 water samples collected from the southern coasts of the Caspian Sea were polluted by mercury. The average mercury concentration detected in water samples was 1.657 mg/l and in fish muscle and liver tissues (*Cyprinus carpio* and *Rutilus frisii kutum* (= *R. kutum*) were the cyprinoids examined) were 68.636 and 125.606 mg/g dry weight, respectively. The bioaccumulation factor showed that mercury concentrations from water to fish were in the range of 14 to 80 times. The highest levels of mercury in water and fish were observed in the southwest coasts of the Caspian Sea.

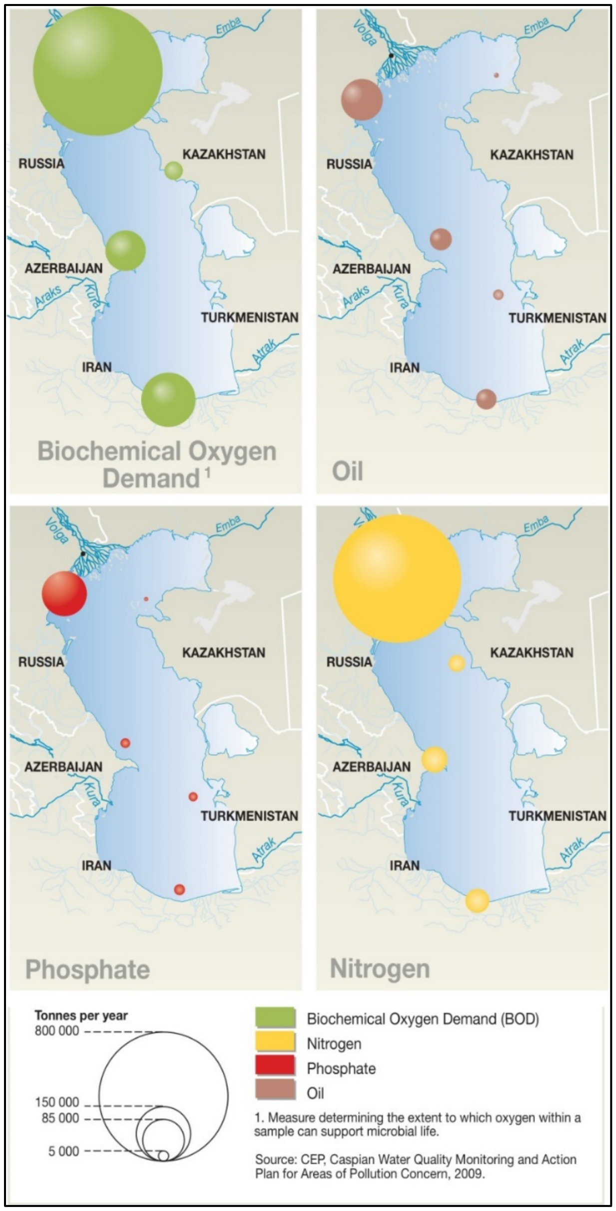
The Volga River draining to the north Caspian Sea is of particular importance. The biology of this river and its effects on the Caspian ecology has been reviewed by Rozengurt and Hedgpeth (1989) and Pavlov and Vilenkin (1989).



Russia, Volga Delta, 2 June 2009
(Earth from Space - Volga Delta, CC BY-SA 3.0 IGO, European Space Agency).

This river is of critical importance for marine fisheries. Fish production is less in the central and southern parts of the sea as nutrient supply comes from upwelling and circulation rather than a riverine input. However, the Volga had effects even here, changing the Caspian Sea from its regime in the 1950s. Abstraction of water for irrigation, industry and household use caused salinity increases of about 0.2-0.3‰, increased aeration of deep layers and in their oxygen content down to 600-800 m by as much as 2-3 ml/l due to convection and thermal winter mixing, an increase in the euphotic zone to 50 m and depths open to total photosynthesis to 100 m, a decrease in organic matter and its vertical gradient, and an increase in wind-driven circulation and its effects on temperature and salinity layers. In the period 1956-1972, the Caspian Sea was transformed from a fishery based on valuable species to one dependent on kilka (*Clupeonella* spp., Clupeidae) which now occupies 80% of the catch (or 107 times the catch in 1930). Even including the kilka, catches in the 1970s were 245 x $10^3$ tonnes or only 37% of the 1913 catch. The catch of Caspian herrings (a complex of species in the family Clupeidae) ceased to exist commercially by the 1970s and in fact was banned. In 1967-1972 it was 0.6-2.1 x $10^3$ compared to 56-62 x $10^3$ in 1945-1953 or 82-307 x $10^3$ in 1900-1917 (Rozengurt and Hedgpeth, 1989). Moghim *et al*. (1994) reported that, in the southern areas of the Caspian Sea, nearly 90% of the catch was composed of *Rutilus frisii* (= *R. kutum*), *Liza saliens* (= *Chelon saliens*, sharpnose mullet) and *Liza aurata* (= *Chelon auratus*, golden mullet) (with biomasses of 24,000, 7,000 and 2,400 t respectively and maximum sustainable yields of 7,000, 2,900 and 960 t respectively).

The Volga is a major pollutant of the Caspian Sea, carrying sewage, agricultural waste, PCBs, petrochemical wastes, tannery waste, etc. from a population base of 60 million people (Golub, 1992). In 1989, 40 million t of polluted wastewater entered the Caspian via the Volga River, more than a quarter of all the wastewater of Russia (www.oneworld.org/patp/pap_overview.html). A report in 1995 gave the volume of pollutants and industrial wastes entering the Caspian Sea each year as 11 billion cu m. Russia accounted for 50%, Azerbaijan 16% and Iran 11% (http://netiran.com/news/IRNA/html/950731IRGG17.html). The Iranian contribution is relatively minor for selected pollutants as illustrated below.




Caspian Sea discharge of pollutants
(Philippe Rekacewicz (le Monde Diplomatique) assisted by
Laura Margueritte and Cecile Marin, later updated by Riccardo
Pravettoni (GRID-Arendal), Novikov, Viktor
(Zoi Environment Network), www.grida.no/resources/5734, UNEP).

The Volga-Don canal in the former U.S.S.R. connected the Caspian Sea with the Black Sea in 1952 and formed an invasion route for various benthic organisms while others came in attached to boats transported by rail or were deliberately introduced (Kasymov, 1982). The molluscs *Abra ovata* and *Mytilaster lineatus*, two invaders, accounted for over 90% of the total benthic biomass. Invaders provided 95.1-99.3% of the total benthic biomass in the western part of the south Caspian Sea in 1976. East of the mouth of the Sefid River, the Azov-Black Sea molluscs *Abra ovata* and *Cerastoderma lamarcki* accounted for 80% of total benthic biomass. In Gorgan Bay, 99.9% of the benthos fauna was comprised of invaders. The Volga is also

connected to the Baltic and White seas via the White Sea-Baltic Canal opened in 1933 (Pavlov and Vilenkin, 1989), another potential invasion route.


Caspian Sea protected areas
(www.grida.no/resources/5734,
GRID-Arendal, UNEP).

The Caspian coastal plain in Iran runs for almost 650 km from Astara (38°26'N, 48°52'E) in the west to Bandar-e Torkeman (= Bandar-e Shah) (36°56'N, 54°06'E) in the east. This plain

has a width of about 25-32 km, but is as narrow as 2 km in places, although it opens out in the east. The Alborz Mountains are almost 1,000 km long, on average less than 100 km wide but very high. Damavand reaches 5,766 m - an estimate - at 35°56'N, 52°08'E and is the highest of any mountain to the west of it in Europe and Asia. It has a continuous snow cover. There are persistent snow fields and Alam Kuh at 4,849 m has small icefields. The north or Caspian slope is very steep and streams tend to be short and torrential, fed by snow melt and year-round rain. However, there are some longer rivers, and the principal ones are detailed below. There are about 128 small to large rivers along the Caspian shore. Nümann (1966) gave some limited biological, chemical and physical data on these streams based on spot recordings. Surber (1969) gave values of total alkalinity and calcium-magnesium hardness for a number of streams and reservoirs along the Caspian shore. Most were moderately to relatively hard and therefore productive for aquatic organisms such as insect larvae on which fish feed. The Caspian Environmental Programme (2001b) gave an overview of habitats and biodiversity along this Iranian shore. Environmentally managed areas were listed along with factors affecting their status under the headings of development, drainage, land use alteration, pollution, destruction of vegetation, over-grazing, mining, hunting and fishing, exotics, dams, and roads. Of 123 fish species only 10 or just over 8% are protected with one protected species on the verge of extinction. Tahami (2018) determined the species composition, and spatial and temporal distribution of plankton and fish in the Goharbaran region of Mazandaran. Cyprinoids were *Cyprinus carpio*, *Rutilus kutum*, *Rutilus rutilus* (= *R. lacustris*) and *Vimba vimba* (= *V. persa*).

Studies on the biology and hydrology of various rivers in the Caspian Sea basin have been carried out by, for example, Roshan Tabari (1995, 1996, and as Rowshan Tabari, 2007) on the Tajan River, Roushan Tabary (1996) on the Haraz River, Roshan Tabari (1997) on the Siah River, Roshan Tabari *et al*. (2001) on the Chalus River, and Ghasemi and Mustafayev (2008) on the Aras River. Most rivers along the Caspian shore have less than 30% of their discharge in the two wettest months and 40% in the six driest months so discharge is well distributed through the year. In contrast, the Gorgan River at the eastern end of the Caspian basin has 70% of its discharge in the two wettest months, figures comparable with drier areas such as Azarbayjan at 50-60% and the Zayandeh and Kor rivers at 40-60%. Annual discharges can vary markedly, e.g., the Lar River had 545 mm on its basin area in 1949-1950 and 1,560 mm in 1950-1951 (Ghahraman, 1958).

The principal Iranian Caspian rivers are described below from west to east, with some associated wetlands. Other major wetlands and water bodies (such as the Anzali Wetland and Gorgan Bay) follow. A stream in the Talar River basin, Mazandaran is the type locality for *Chalcalburnus chalcoides iranicus* (= *Alburnus chalcoides*), the Kheyroud River in Mazandaran is the type locality for *Capoeta razii* and the southern Caspian Sea and its tributaries are the type locality for *Leuciscus frisii* var. *kutum* (= *Rutilus kutum*). The Keselian or Kesselian (= Kaslian) River or Stream is in the Talar River basin and has been studied for its fish fauna (and it is the type locality of the cobitid *Cobitis keyvani* (= *C. faridpaki*)).

Mazandaran, Kaslian River, Soheil Eagderi.

The Aras (= Araks, Araz, or the Classical Araxes) is a tributary of the Kura River of Azerbaijan. The Kura rises in Turkey and is 1,510 km long. The Aras forms the border between Iran and the former U.S.S.R. (now Azerbaijan and Armenia) for 430 km and has its source near Erzurum (39°55'N, 41°17'E) in Anatolian Turkey and the headwaters of the Euphrates River. Its total length is 1,072 km. Its whole basin is 102,000 sq km, making it one of the largest rivers in the Caucasus Mountains. The Aras can be wide and meandering with braided channels and backwaters. Depth range of the Aras is 0.5-4.0 m, average 2.5 m (Zakeri, 1997). The Aras is one of the largest rivers in Iran. The Kura-Aras basin encompasses 225,000 sq km of which 28,000 sq km or 12.4% is found in Iran (Gleick, 1993). Azerbaijan discharges 303 million cu m of waste into the Caspian Sea annually according to Golub (1992), presumably through the Kura and other major rivers. Derzhavin (1929a) gave an interesting account of the formation of a new channel of the Aras north of the Iranian border in 1896 which led to the freshening of the Kyzylagach Bay. This favoured migrations of fishes into the Kura River. However, irrigation schemes on the Mugan steppe severely reduced catches as well as causing salinisation of soil. Water abstraction prevented entry of adequate numbers of sturgeons (and presumably cyprinoids) onto the Kura spawning grounds. This type of water usage is paralleled along the Caspian shore in Iran with deleterious effects on a variety of sedentary and migratory fish species. The ichthyofauna of part of this basin in northwestern Azarbayjan is reviewed by Yahyazadeh *et al*. (2007, 2015) and Gürbüz (2020) referred to *Squalius turcicus* as an endemic in this transboundary Turkish river. The records of *Leuciscus lehmanni* Brandt, 1852 and *Leuciscus squaliusculus* (Kessler, 1872) (= *Petroleuciscus squaliusculus*) are presumably errors, possibly misidentifications of *Squalius turcicus*, as they are found naturally in Central Asia in Afghanistan and Uzbekistan and in the Syr Darya drainage of Kazakhstan, Kyrgyzstan and Tajikistan, respectively. They may possibly have been introduced along with Chinese major carps if these were sourced from Central Asia but there are no other records of these species in Iran despite the wide distribution of introduced carps. Zazanashvili *et al*. (2020) listed the Aras River as important for fish conservation in their Ecoregional Conservation Plan for the Caucasus.

The Aras River at Jolfa, Azerbaijan opposite Iranian Jolfa is a type locality for *Chondrostoma leptosoma* (= *C. cyri*), the Aras River opposite Jananlo, East Azarbyjan in Iran is the type locality of *Capoeta kaput*, and the Balyk River in the upper Aras River basin near Ardabil in Iran is the type locality for *Leuciscus cephalus orientalis* natio *ardebilicus* (= *Squalius turcicus*).

Aras River basin
(IranCatchMaz1, CC BY-SA 4.0, Mahdy Saffar).


Kura River basin map (Kurabasinmap, CC BY-SA 4.0, Shannon1).

The Araxes or Aras Dam, a 40 m high embankment dam downstream of Pol Dasht in West Azarbayjan Province, was a joint Iranian-Soviet project on this river. Sabkara and Makaremi (2013) described the density and distribution of plankton in the dam, in reference to fish culture. Alizadeh Osalou *et al*. (2015) gave details of water quality in the dam and the river and found the dam to be eutrophic. Mohebbi *et al*. (2016) also assessed water quality of the dam using phytoplankton communities and their relationship with environmental factors. Results showed the cyanobacterial bloom pattern had shifted from the warm season to an all year-round cycle caused by polluting anthropogenic activities and global warming, and the reservoir was eutrophic with consequent effects on fisheries. Iranian authorities stocked this dam with 1.8 million fingerlings (species not specified) weighing over 10 g each in 1997 to enhance fish farming (*Islamic Republic News Agency*, 29 December 1997). However, Seidgar *et al*. (2020) found carrying capacity, shortage of freshwater sources and hypertrophic conditions made the dam unsuitable for cage culture of fishes.

West Azarbayjan, Aras River and Dam
(Khoda Afarin bridges, CC BY-SA 3.0, Abdossamad Talebpour).

Other dams are under construction. The Khoda Afarin Dam downriver from the Aras Dam, 8 km west of Khomarlu in East Azarbayjan Province, is also an embankment dam. Zareh Reshquoeeieh *et al*. (2016) investigated heavy metals in this dam and found concentrations of arsenic and cadmium, but not copper, in *Abramis brama*, *Capoeta capoeta* and *Cyprinus carpio* were above acceptable levels.

East Azarbayjan, Khoda Afarin Dam
(KhodaAfarin Dam, CC BY-SA 3.0, Abdossamad Talabpour).

Fataei *et al*. (2012) identified anthropogenic influences on water quality of the Aras River at nine sampling stations including residential wastewater, sewage, city landfills, agriculture, fish farms and industrial activities, as well as erosion from weathering and floods, and gave descriptive statistics of water quality variables. Nasehi *et al*. (2012) recorded pollution in the Aras River from agriculture, city waste and industry and detailed levels of cadmium, copper, iron, lead, mercury, nickel and zinc at five stations over four seasons. Masoumian (2007) reported on parasites of fishes from the Aras, Ghotor and Zangbar rivers in West Azarbayjan.

Akh Gol occupies 600 ha at 820 m in the Aras River valley in northwestern Iran (Scott, 1995). It comprises a small brackish lake with associated marshes and springs and drains to the Aras 5 km away. The area is being converted to agriculture and the lake is being drained.

Principal tributaries of the Aras in Iran are the Qareh Su (= black water, draining easily eroded, volcanic soil) draining from the Kuhha-ye Sabalan at 4,810 m (38°15'N, 47°49'E) near Ardabil (38°15'N, 48°18'E) and the Qotur River draining past Kuh-e Zaki at 3,079 m on the Turkish border through Khvoy (38°33'N, 44°58'E) to the Azerbaijan border near Jolfa (38°57'N, 45°38'E).

Ardabil, Qareh Su at Samian Bridge 15 km from Ardabil
(CC BY 4.0, *Tasnim News Agency*).

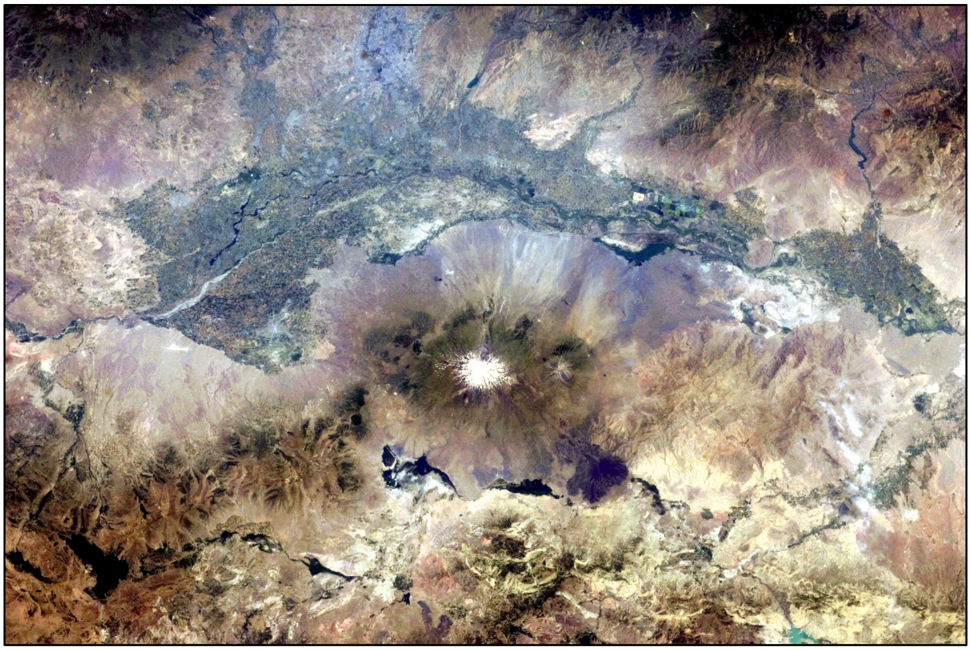
Delshad *et al*. (2018) examined water samples in the Qareh Su at four stations near *Oncorhynchus mykiss* (rainbow trout) farms and found effluents between farms and downstream showed the greatest impact on water quality. Hoseini (2019) studied the self-purification and water quality of the Qareh Su over a length of 90.6 km, finding variation with season and location. The 240-km-long Ahar Chay is a Qareh Su tributary on which lies the Sattarkhan Dam, the construction of which resulted in a more eroded downstream with a major decrease in sediment supply with, presumably, concomitant effects on fishes (Ashouri *et al*., 2013). Rahimibashar *et al*. (2016) examined water quality and macrozoobenthos and found this river had very good water quality, well-balanced natural habitats and relatively low pollution. However, excessive water withdrawal from the Ahar Chay to irrigate orchards and farms led to a fish kill in June 2017. Household waste probably contributed to the problem (*Financial Tribune*, 1 July 2017). The dam has suffered from drought in recent years.

East Azarbayjan, Sattarkhan Dam (CC BY 4.0, Hasan Balagar).

The Balekhlu-Chay, Balekhloo or Balekhlu River is another Qareh Su tributary which feeds the Yamchi Dam, a water source for the city of Ardabil. Pollution for the river was wastewater from residential, industrial, agriculture and hot spring sources. Eight fish, including five cyprinoids, were used in a bioassessment and pollution ranged from low in two stations, moderate in two stations and high in one station (Jafarzadeh *et al*., 2015). The cyprinoids were *Alburnoides bipunctatus* (= *A. eichwaldii*), *Alburnus alburnus* (= *A. hohenackeri*), *Barbus lacerta* (= *B. cyri*), *Capoeta capoeta gracilis* (= *C. capoeta*), *Carassius auratus* and *Squalius cephalus* (= *C. turcicus*). Babaei *et al*. (2016) found low levels of heavy metals and pesticides at the Yamchi Dam outlet, so river water was suitable for aquaculture. Sabkara *et al*. (2016) examined the plankton communities in the Yamchi Dam, assessing them as suitable for aquaculture. Valipour *et al*. (2017) studied trout aquaculture potential downstream of the dam, with up to 4,000 t possible using a semi-recirculation system. Salavatian *et al*. (2017) studied macrobenthos biomass in the Arasbaran Dam in Ardabil Province on the Silin Chay in the Aras River basin for aquaculture use. The natural production capacity of the lake was estimated at about 0.2-1.7 kg/ha. Abbasi *et al*. (2017) recorded *Barbus cf. cyri* (the only native species), *Carassius gibelio, Cyprinus carpio, Hemiculter leucisculus* and *Pseudorasbora parva* as the cyprinoids in this dam. *H. leucisculus* comprised 85% by beach seine and *Cyprinus carpio* was the only species caught by gill nets.

Ardabil, Balehklu River in Ardabil
(Three springs in Ardabil (in Farsi), CC BY-SA 4.0, lightened, Esmailboroomand).

Ardabil, Balehklu River, Hamid Reza Esmaeili.



Aras River valley on Turkey-Armenia border with Mt. Ararat at centre, Iran on lower right (CC0, NASA).

East Azarbayjan, Aras River on Iran-Azerbaijan border near Jolfa
(Aras River, Iran ^ Azerbaijan border, CC BY 3.0, Hadi Karimi).

East Azarbayjan, Aras River on Iran-Azerbaijan border near Jolfa
(Jolfa-Aras2, CC BY-SA 3.0, M. Kazarj).

Abbasi *et al*. (2011) summarised the abundance and diversity of fishes in the Kargan River of northern Gilan, and found 18 species with Cyprinoidei having 10 species and over 90% of the total population. *Alburnoides eichwaldii* (*sic*, presumably *A. samiii*), *Capoeta capoeta* (= *C. razii*) and *Alburnus hohenackeri* were dominant with 29.58%, 29.15% and 19.87% respectively. Ten species were freshwater residents, four species were migratory and four were estuarine or marine. Five species were recognised as aliens.

The Sefid (= Safid or White from its sediment load, up to 60 g/l) River, the Classical Amardos, is the only one to completely pierce the Alborz Mountains and have a considerable basin on the plateau. Japan International Cooperation Agency and CTI Engineering Co. Ltd. (2010) studied integrated water resources management in this river basin which encompasses 59,090 sq km over eight provinces. There are 174 dams or dam projects in this basin, indicating major changes in natural fish habitats. Protected Areas are briefly described, water quality values given, qanats, springs, weirs and canals mapped, and demand for water used for fish culture listed for various areas, among other descriptors relevant to fish for this basin. Treatment of the fish fauna *per se* was cursory.

A stream in this river basin is the type locality for *Alburnus pseudospirlinus* (a hybrid of *A. hohenackeri* and *Alburnoides bipunctatus* (*sic*, presumably *A. samiii*)).

Various sources give differing accounts of the Sefid River length, up to 800 km. It is the second largest river in Iran. The Sefid has the greatest mean discharge of Iranian Caspian rivers, over three times that of the Haraz, the next most important. In flood the Sefid discharge is twice that of the Karun River in the Tigris River basin, but its minimum is less than a tenth, because the Karun drains a greater area with higher elevations and a more extensive snow pack. The Sefid discharge is 4,000 cu m per second at maximum, falling to only 15 cu m per second. An average discharge is 182.17 cu m per second. There used to be two freshets before the dam was

constructed at Manjil, one fed by spring snow melt in March-May and one by rainfall in the autumn.

The width of the Sefid River varies from 100 to 250 m and depth from 2 to 8 m. The average instant yield is 128.79 m/sec, range 76.5-288.5 m/sec. The average annual yield is 3,998.4 million cu m (Zakeri, 1997). Babaei *et al*. (2017) examined levels of copper, lead and zinc in the Sefid River, lead being higher than permissible levels.

Sefid River basin
(IranCatchMaz3, CC BY-SA 4.0, Mahdy Saffar).


Sefid River basin
(Sefidrivermap, CC BY-SA 3.0, Kmusser).

Gilan, Sefid River east of Rasht near the highway bridge,
3 March 1968, Neil B. Armantrout.

Gilan, Sefid River near Astaneh-ye Ashrafiyeh
(Sefidrood2, CC BY-SA 4.0, Sajbadina).

Gilan, Sefid River near Rasht
(Sefidrood, Guilan, CC BY-SA 3.0, Sepehr240).

Gilan, Sefid River on Rasht-Tehran road, 12 October 1974, Neil B. Armantrout.

Gilan, Sefid River near Jubon
(Sefidrud Gilan rostamabad - panoramio, CC BY 3.0, cropped, Alireza Javaheri).

The Sefid is formed from the Qezel Owzan (Qizil Üzan or Red River) from the west and the Shah River or Shahrud (= King River) from the east that meet on the plateau and flow through a narrow gorge. This gorge is dammed by what was named the Shahbanou Farah Dam at Manjil (now the Sefid River or Manjil Dam) (dam height 106 m, length 425 m; reservoir 1,860 million cu m, surface area 56 sq km maximum, 14 sq km minimum, maximum depth 80 m, minimum 30 m, summer temperature 24°C, winter 7°C, pH 7.8, 31 g/l turbid materials, $Cl^-$ 229 mg/l, $SO_4$ 178 mg/l). Strong water level fluctuations prevent the development of a belt of vegetation and the heavy sedimentation inhibits a bottom fauna. Khodjeini and Mohamed (1975) detailed the rate of sediment accumulation in this dam, 757 cu m/sq km/year, evidence of severe

erosion of a devegetated drainage basin. The reservoir was half filled with sediment after only 20 years despite an expected life span of 100 years. The reservoir is apparently drained at intervals to remove some of the accumulated sediment. This would severely affect littoral spawning and feeding habitats for fishes. Nümann (1966, 1969) gave details on the limnology of this reservoir. The dam decreased turbidity in the river, raised water temperatures at the river bed in summer and caused marked diurnal temperature changes. This prevented ascent of *Salmo caspius* (Caspian trout) to the upper reaches and the dam itself prevented ascent of *Rutilus caspicus* (= *R. lacustris*). Nümann (1966) recommended introducing *Sander lucioperca* (pike-perch), *Acanthobrama terraesanctae* (a Levantine species) and cichlids to the reservoir.

Gilan, Manjil Dam reservoir, 8 June 1978, Brian W. Coad.

Gilan, Manjil Dam
(CC BY 4.0, *Tasnim News Agency*, 8 May 2019).

Gilan, Manjil Dam and Sefid River
(Manjil Dam in Gilan province in 2019 …., CC BY-SA 4.0, Mardetanha).

The Taleghan, Talaqan or Taleqan Dam (12.8 sq km in area) is found in the Shah River basin. *Oncorhynchus mykiss* (rainbow trout) farms in this basin have been examined by Dadgar *et al*. (2014) for their effects on water quality which decreased in some tributary waters but the Shah River's high flow reduced impacts. The water quality of the Taleqan River was assessed by Vaghefi *et al*. (2012) as medium to good.

Alborz, Taleqan Dam
(Taleghan Dam, CC BY-SA 3.0, M. Samadi).

Alborz, Taleqan River
(Taleghan River, CC BY 3.0, Alireza Javaheri).

Sarpanah *et al*. (2004) found 45 species and subspecies of fish in the Sefid River basin with 29 of these economically important. Thirteen species were migratory, 11 species estuarine and the rest resident. Thirty-six species were recorded as endemics (presumably native) with the rest exotics and migrants. The Boojagh or Bujagh National Park encompasses the estuary or delta of the Sefid River in Gilan has 25 species and subspecies of fish (Khara *et al*., 2004). Sadeghi Zadegan (2018a) gave a brief overview of Bujagh National Park which includes the Bandar-e Kiashahr Lagoon. The park is an important spawning and nursery area for fishes such as migratory *Rutilus kutum* and *Vimba persa* which enter the Sefid River at the end of winter and beginning of spring to spawn. There is an important commercial fishery and also poaching of kutum, *Rutilus kutum*, and sturgeons. The park has a research centre which breeds kutum for restocking. Khoshravan *et al*. (2021) evaluated changes in the park from 1978 to 2019 occasioned by Caspian Sea water level fluctuations. The most important habitats affected were coastal lagoons, dry and wet sandy beaches, fluvial meadows and the river estuary as a large part

of the coastal wetlands dried up. Khara *et al*. (2011) described the water quality of the Oshmak River which flows through the park. Mean air temperature was 19.63$^{o}$C, mean water temperature was 65.17$^{o}$C (*sic*, from abstract), mean turbidity was 29.40 FTU (Formazin Turbidity Unit), mean conductivity was 1114.95 micromus/cm, mean total dissolved solids was 678.03 mg/l, mean total suspended solids was 38.58 mg/l, mean total alkalinity was 77.75 mg/l, mean total hardness was 412.25 mg/l, mean $Ca^{+2}$ was 68.14 mg/l, mean $Mg^{+2}$ was 60.44 mg/l, mean $Cl^{-}$ was 133.45 mg/l, mean $SO_4^{-2}$ was 152.64 mg/l, mean $PO_4$ was 0.08 mg/l, mean total phosphate was 0.63 mg/l, mean $NH_4$ was 0.34 mg/l, mean $NO_2$ was 0.05 mg/l, mean $NO_3$ was 0.81 mg/l, mean dissolved oxygen was 7.24 mg/l, mean biological oxygen demand was 9.83 mg/l, mean chemical oxygen demand was 34.61 mg/l, mean salinity was 490 mg/l, mean pH was 7.75, mean acidity was 5.50 mg/l, mean free $CO_2$ was 4.48 mg/l, mean total coliform was 33,541 no/100 ml/l and mean faecal coliform was 5,363 no/100 ml/l.

The 500 ha Bandar-e Kiashahr Lagoon (= Bandar-e Farahnaz) Ramsar Site (World Conservation Monitoring Centre, 1990) at 37°25'N, 49°19'E east of the mouth of the Sefid River was a freshwater coastal lagoon and swamp fed by two streams from the Sefid River to the west and draining to the Caspian Sea via a channel to the north. A rise in Caspian Sea level converted this area into a bay of the sea as it was in the 1950s before the fall in sea level (Khan *et al*., 1992). The lagoon bed is sand and mud and the water was oligotrophic except near the marshes to the west. There were reedbeds of *Phragmites communis*, *Typha* and *Juncus*, now restricted to the extreme west end. There were several factors affecting this habitat including a fishery with a fish-processing warehouse, grazing, reed cutting, irrigation abstraction and recreational activities. It was an important spawning and nursery ground for fishes (effects of recent changes unknown) and is still an important centre for commercial fishing.

Lower dams on the Sefid, such as the Tarik (10 m high) and the Sangar (3 m high), divert water for irrigation purposes on the Gilan plain, the former through a 16.7 km long tunnel. Construction of the Alamut Dam in the upper reaches of the Sefid River basin would affect such species as *Luciobarbus mursa*, prized for sport fishing, which would need full habitat protection to survive (Aghili *et al*., 2008). *Salmo trutta* (= *S. caspius*, Caspian trout) would not need protection as its habitat is confined to a stretch of river above the dam.

The Sefid breaks up into distributaries near its mouth and its flow is carried off into a complex of canals and irrigation ditches. The Sefid has changed its delta several times, (Vladykov, 1964). In 1911 it shifted 2-3 km east from the fishing post of 12 Bahman to Hasan Kiadeh. An account in Farsi on the Sefid River was given by Wossugh-Zamani (1991a).

The headwaters of the Qezel Owzan lie in Kordestan, near the Iraqi border, and so drain part of the northern Zagros Mountains as well as areas near Lake Urmia such as the Kuh-e Sahand (37°44'N, 46°27'E), mountains near Hamadan (34°48'N, 48°30'E) and the southern slopes of the Alborz Mountains. The Qezel Owzan is about 550 km long. Kazemian *et al*. (2009) studied fish diversity and abundance in the Qezel Owzan in Zanjan Province, finding nine cyprinoid and one nemacheilid species. *Capoeta capoeta gracilis* (= *C. razii*), *Alburnoides bipunctatus* (*sic*, presumably *A. samiii*) and *Luciobarbus capito* were the most abundant at 33.6%, 22.1% and 13.1% of the total number of fishes caught. The greatest diversity was in a downstream station.

Qezel Owzan
(Qizil Üzan, CC BY-SA 4.0, Samak).

Zanjan, Qezel Owzan River, 6 June 1978, Brian W. Coad.

East Azarbayjan, Pol-e Dokhtar Bridge over Qezel Owzan River near Mianeh, Flandin (1840).

East Azarbayjan, Pol-e Dokhtar Bridge over Qezel Owzan River near Mianeh, 2013 (Kizil Hausen Bridge 2013, CC BY-SA 3.0, Sj.jamali).

Khoshnazar and Nasrabadi (2013) evaluated water quality in the Qezel Owzan at eight stations finding turbidity and biological oxygen demand were bad at one station during high water, for example, but generally water quality indices were rated as medium to good, with some pollution from domestic wastes.

The Taham Dam or Lake 12 km northwest of Zanjan lies in the Qezel Owzan basin on the Taham Chay. This dam is 120 m high with a crest length of 450 m and a capacity of 82.7 million cu m. A limnological study of this early stage mesotrophic lake was provided by Mirzajani (2010) and Mirzajani *et al*. (2012). Cyprinoids in the dam included *Alburnoides bipunctatus* (= probably *A. samiii*), *Capoeta capoeta* (= *C. razii*) and *Leuciscus cephalus* (= *Squalius turcicus*) as the most abundance in the catch. *Carassius auratus* and *Alburnus filippii* were also present. "*L. cephalus*" was recorded with a maximum size of 870 g while the most frequent weight class was 150-450 g for "*C. capoeta*". "*L. cephalus*" attained a commercial size and high abundance and a fisheries management programme in Taham Lake would be needed for sustainable exploitation. Golabar Dam or Lake 55 km southwest of Zanjan has been investigated for aquaculture by Yosefzad *et al*. (2014) based on macrobenthos production. The fisheries potential production was estimated 2.9 kg/ha for benthivorous fishes. Babaei *et al*. (2016) etimated the lake could support 369 t of trout (*Oncorhynchus mykiss*) production. Babaei (2017) carried out a limnological study and found the recently constructed dam to be in a eutrophic state already. The cyprinoid fish fauna comprised *Alburnoides bipunctatus* (= probably *A. samiii*), *Alburnus alburnus* (= possibly *A. hohenackeri*), *Alburnus filippii*, *Barbus lacerta* (= *B. cyri*),

*Capoeta capoeta* (= *C. razii*), *Carassius auratus*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *H. nobilis*, *Pseudorasbora parva* and *Squalius cephalus* (= *S. turcicus*). The fish fauna behind the earth dam at Maljiq, 50 km southwest of Hashtrud in the upper Qezel Owzan basin, suffered severely in the drought of the year 2000. Twenty-five tonnes of fish died after the reservoir dried up (*Islamic Republic News Agency*, 30 July 2000). Sadeghinejad Masouleh (2018) studied the Qhar-khetlu Dam in the central part of Ijrud City, southwest of Zanjan in the Qezel Owzan basin. The reservoir has a volume of 500,000 cu m. Minimum and maximum temperatures of water ranged from 4.5 to 26°C, the pH was 4.7 to 8.8, the dissolved oxygen was 7.7 to 12.2 mg, the total water hardness fluctuation was 154 to 194 mg/l, electrical conductivity was 272 to 390 µm/sq cm, and the water transparency was 25 to 380 cm. Conditions were suitable for the introduction of warmwater and coldwater fishes including silver carp, bighead carp, rainbow trout and native fishes including species of *Barbus* (presumably *Luciobarbus*) and *Capoeta*. Estimation of the reservoir production was 80 kg/ha and its production capacity was 484 kg/year.

The Zanjan River is a right tributary of the Qezel Owzan River flowing west from the Aq Daq Mountains through Zanjan joining the Qezel Owzan River near Rejeen. Its upper reaches approach those of the Abhar River of the Namak Lake basin. Abdollahi *et al*. (2019) identified environmental risks (residential, industrial, sewage and agricultural pollution) in this river and suggested means to mitigate them.

The Shah River is much shorter (ca. 175 km) than the Qezel Owzan and drains the southern Alborz as far east as Takht-e Soleyman at 4,819 m (36°22'N, 50°58'E). Mahmoudifard (2015) used benthic invertebrate populations to assess water quality in the Shah River at eight stations and found a decrease downstream and where agricultural, industrial and residential sewage was received. The river was assessed at a low polluted level. Sharifinia *et al*. (2016) compared physico-chemical and macroinvertebrate-based indices of pollution in this river at eight sampling sites and found the latter were more powerful indicators in assessing water quality which ranged from very good at the upstream to poor at downstream sites.

Qazvin, Shah River valley
(Qazvin - Alamout - Razemian Valley, CC BY 3.0, Alireza Javaheri).

The Totkabon, Tootkabon, Totkebon or Tutkabon Stream or River is the type locality of *Alburnoides samiii*, and is a tributary of the Sefid River. The river is about 23 km long and at 175-200 m above sea level has a 0.55-0.69 cm depth, 2.8-4.2 m width, 0.6-0.75 m/s water velocity, slope of 0.5-1.75%, a stone diameter of 25-30 cm, cobble and then boulder substrate type, deciduous riparian forest, and with the most available cover type being boulders (Asadi *et al*., 2016). Zamani Faradonbe *et al*. (2017) studied niche overlap among fishes from this river. The presence-absence and abundance of *Alburnoides samiii* were related to elevation, depth, number of large stones, stone diameter and velocity, for *Barbus cyri* to number of large stones, stone diameter, velocity, elevation and depth, and for *Acanthobrama microlepis*, *Carassius auratus* and *Pseudorasbora parva* to large stones, slope, elevation and depth. *B. cyri* and *Capoeta gracilis* (= *C. razii*) occupied all possible habitats due to their high adaptability to a large range of environmental factors, *A. samiii* was in deep areas of the river where pools were abundant, and *C. auratus* and *P. parva* were found near banks among vegetation and slower water. Further details of this habitat can be found under the *A. samiii* species description. Moëzzi *et al*. (2018) evaluated the performance of four models (multiple linear regression, partial least square regression, support vector machines and random forest) in the prediction of biodiversity indices in fishes of the Tutkabon River. In addition, the importance of environmental parameters in the prediction of those indices was calculated. Multiple linear regression and partial least square regression had a weak performance while support vector machine and random forest had the best performance. Various environmental parameters had varying importance across the examined models. Support vector machines and random forest were suggested as suitable models for prediction of biodiversity indices of the southern Caspian Sea fishes.

Gilan, Tutkabon River
(Gilan - Tutkabon - panoramio, CC BY 3.0, Alireza Javaheri).

The Shalman River in eastern Gilan is a tributary of the Langarud near its mouth. The Langarud is called the Chamkhaleh River near its mouth.


Gilan, Chamkhaleh River (CC BY 3.0, cropped, Kasir).

The Shalman River was sampled by Shahnazari *et al*. (2020) who described the frequency, distribution and biodiversity of freshwater and estuarine fishes from seven sites with 5 km intervals, from an altitude of 371 to -28 m. The cyprinoids were *Alburnoides samiii*, *Alburnus chalcoides*, *A. filippii*, *A. hohenackeri*, *Barbus lacerta* (= *B. cyri*), *Capoeta razii*, *Carassius gibelio*, *Luciobarbus capito*, *Pseudorasbora parva*, *Rutilus kutum* and *Squalius orientalis* (= *S. turcicus*). *Alburnoides samiii* was the most numerous species at a frequency of 14.72% followed by *Capoeta razii* at 14.42%. The presence of endemic species and a significant decrease in large fishes in this river, probably due to overfishing, pollution and toxins, showed that this habitat needs protection.

Soufi *et al*. (2010) summarised the effects of human-related factors on the biodiversity of the Shomast (Mazandaran) and Solokli (Golestan National Park) lagoons although the only fish mentioned was *Cyprinus carpio* in the former lagoon. Waste from tourism and washing vehicles were polluting factors in the Shormast Lagoon.

The Cheshmeh Kileh River enters the Caspian Sea at Tonekabon (or Shahsavar - and the river has all three names in various literature sources) in Mazandaran and is significant for its migratory populations of *Rutilus kutum* and *Salmo caspius* (Caspian trout). The river is about 80

km long. Aquaculture, sand removal, urban and industrial pollution and agriculture all affect the natural environment. Fadavei Hosseini *et al*. (2010) recorded water quality at the inlets and outlets of two trout farms on the Do Hezar River (a Cheshmeh Kileh tributary) and found lower oxygen levels at the outlets as well as significant differences in ammonium, nitrate, nitrite and phosphate levels. Trout farming was still considered sustainable and impacts on the ecosystem were acceptable. Abbaspour *et al*. (2013, 2014) documented macrobenthos composition over the course of a year and showed untreated wastewater from urban areas was the primary source of low water quality. Karbassi *et al*. (2013) documented flocculation of copper, lead, manganese, nickel and zinc during mixing of estuarine Cheshmeh Kileh River water with Caspian Sea water. This process was important in self-purification of heavy metals in rivers. Gravel removal was also a detrimental factor to fish populations, at least in the 1960s (see below).

Mazandaran, Shahsavar River (Tonekabon or Cheshmeh Kileh River), fish traps, 13 April 1968, Neil B. Armantrout.

Mazandaran, Shahsavar or Tonekabon River showing gravel removal,
13 April 1968, Neil B. Armantrout.

Boudaghpour and Monfared (2008) listed the effects of gravel and sand removal as darkening and spoiling fish flesh due to reduction in oxygen for body texture, sediment covering eggs, destruction of spawning beds, damaging fertilised eggs and decreasing larval populations, loss of food sources, and disordering gaseous exchange around eggs and so increasing the period of incubation. They noted that the fish population in the Cheshmeh Kileh (= Tonekabon) River in Mazandaran was drastically reduced by gravel and sand removal. Rowshan Tabari *et al*. (2015) carried out a risk assessment of sand and silt exploitation in the Tonekabon River noting cyprinids (= cyprinoids) had the highest diversity and abundance. Migration and artificial propagation of Caspian salmon *Salmo trutta caspius* (= *Salmo caspius*) and *Rutilus frisii kutum* (= *Rutilus kutum*) in this river were of high importance. Destabilisation of river substrate and increase of suspended solid led to reduction in diversity and abundance of species. Alizadeh Sabet (2017b) documented sand mining, establishment of large factories next to the river, legal and illegal trade of river sediments, direct entry of Tonekabon landfill leakage into the river, development of rainbow trout farms over three decades and escape of trout into the river, and huge effluent loads.

Ghorbani *et al*. (2019) sampled water and macrobenthic fauna up to 750 m below a rainbow trout (*Oncorhynchus mykiss*) farm on the Daryasar River, western Mazandaran. Farm effluent was not significantly different for many physicochemical parameters except nitrate and phosphate and biotic indices indicated a healthy river. This was attributed to the low production capacity of the farm and its suitable management.

The Haraz (or Heraz) River drains the Alborz east of Tehran and has a number of longitudinal tributaries in the mountains. These depend on snow melt and are cold even in summer. Fishes are reported to be present in these high streams, but were not easily caught. The Haraz debouches onto a plain and splits up into distributaries. It was polluted from *Oncorhynchus mykiss* (rainbow trout) farms (Kazemzadeh Khajuie *et al*., 2002; and see above) and heavy metals (lead and cadmium) were present in fish (Riahi Bakhtiyari, 2001, 2002). Kavian *et al*. (2016) examined 17 stations for water quality and found it to depend strongly on

land use, landscape type and human presence. Water quality deteriorated towards the downstream stations. The Haraz River pesticide levels were detailed by Mohammad Shafiee (2001). Banagar *et al*. (2008, 2009) recorded the fish biodiversity as 20 species in nine families, dominated by cyprinoids at 67.2% and with 70% of species resident, the rest anadromous. Exotics were *Oncorhynchus mykiss* (rainbow trout), *Carassius auratus*, *Liza saliens* (= *Chelon saliens*, sharpnose mullet), *Gasterosteus aculeatus* (threespine stickleback) and *Gambusia holbrooki* (eastern mosquitofish). Afraei Bandpei *et al*. (2018) examined the distribution and species diversity in the Haraz River and found a decrease in cyprinoid diversity with no *Barbus* (*sic*) spp. caught and such species as *Alburnoides eichwaldii* (*sic*, presumably *A. tabarestanensis*, possibly *A. samiii*), *Capoeta capoeta* (= *C. razii*) and *Squalius cephalus* (= *S. turcicus*) at a very low abundance, the causes being aquaculture and sand and gravel extraction resulting in increased water turbidity affecting eggs and larvae.

Mazandaran, Haraz River
(CC BY-SA 3.0, Mirasir).

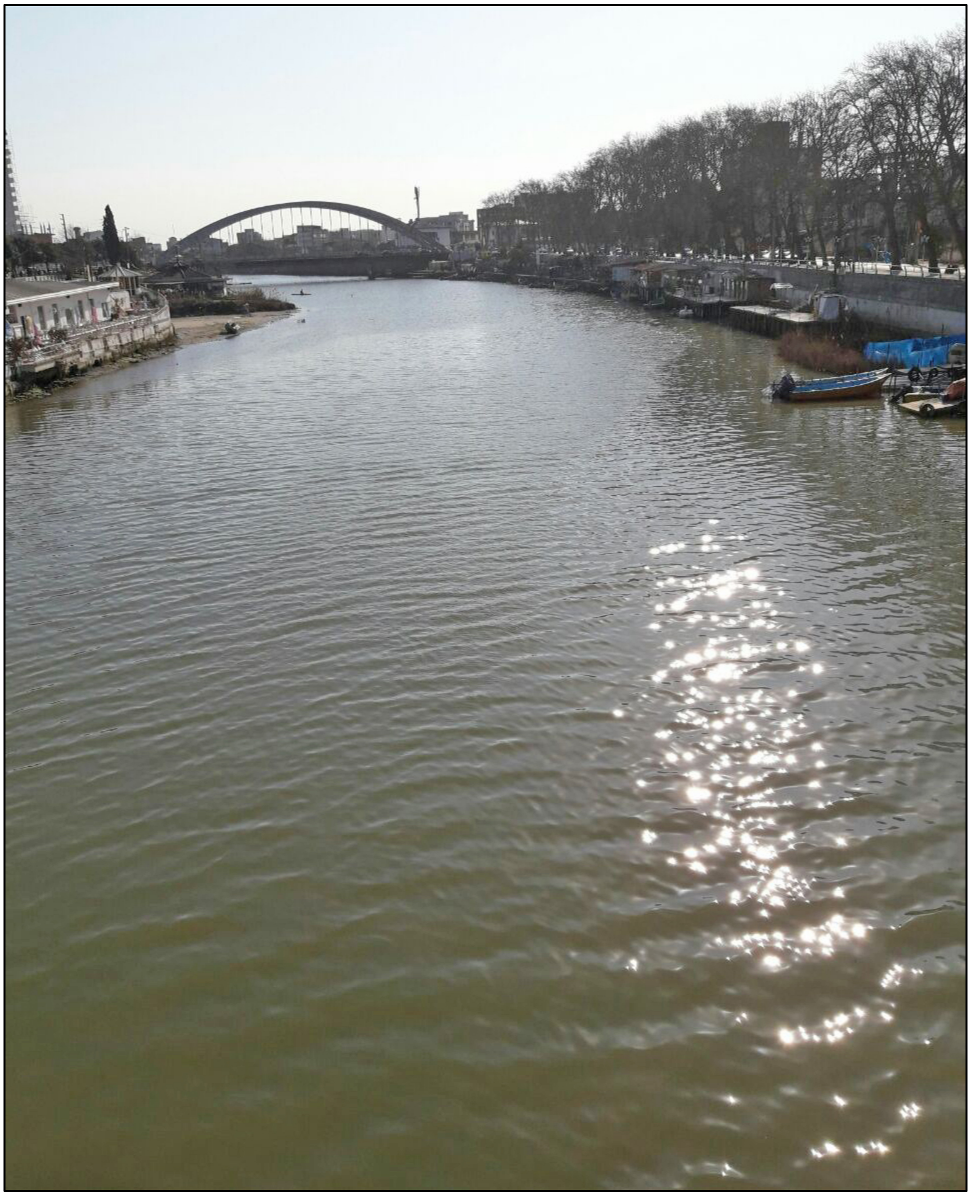
Mazandaran, Haraz River 20 km above Amol, 18 April 1968, Neil B. Armantrout.

Mazandaran, Haraz River near Kandelu
(Kandelu 9, CC BY-SA 4.0, MRG90).

Mazandaran, Haraz River near Ab-e Ask (Haraz Road 04, CC BY 2.0, ninara).

The Babol River, with a mouth at 36°43'N, 52°39'E at Babolsar, is 78 km long, has a watershed of 1,630 sq km, is 50-60 m wide at its mouth and has an average discharge of 16 cu m/sec. Ghoroghi *et al*. (2013) noted that this river was very suitable for fish breeding and spawning and gave details of hydrology and hydrobiology. The river was divided into four reaches. A: Length of about 4 km from the estuary containing fresh and brackish water with a general slope of 0-1% in this coastal region; B: Length of about 16 km (20 km from the estuary) with low water flow and a slope of 0-2%, the river bed having a medium texture. The Babol and Babolsar Amir Kola sewage containing oil fall into this reach of the river as does waste from the Babol slaughterhouse. Pollution affects fish spawning and migration due to its proximity to the estuary; Area C: This reach is almost clear water with a rocky bed and a length of about 44 km (64 km from the estuary). The slope and topography of the area is low; Area D: This area has an average slope of 2-5%, the terrain is very variable and it is located at an altitude of about 1,500 m above sea level. Water in this area is rich in oxygen and flow is very high. The Savad-koh forests surround part of the river. Behmanesh (2016) studied the water quality of the Babol River and found the index varied from good to very poor, with only one station of seven ranking as good.

Mazandaran, Babolsar with kilka boats
(Babolsar-Mazandaran-Iran - panoramio, CC BY-3.0, Amin-Sh).



Mazandaran, Babol River
(Bridge babolrood, CC BY-SA 4.0, Zpashna82).

The Alborz Dam on the Babol River has a height of 78 m and a volume of 150 million cu m. It provides irrigation, flood control and fisheries.

Mazandaran, Alborz Dam
(Alborz Dam v 02 - panoramio, CC BY-SA 3.0, A. H. Mansouri).

The Tajan, Tejan or Tadjan River was studied by Ro(o)shan Tabari (1995, 1996) who reported on its hydrology and biology. It is the type locality for *Alburnoides tabarestanensis*. Its mouth lies at 36°49'N, 53°05'E. The maximum flow is in April, decreasing from May onward. In April 1989 flow was 45 cu m/sec falling rapidly to 0.11 cu m/sec in June. Over 70% of the fishes are anadromous with sturgeons being the most important species (*Acipenser persicus, A. gueldenstaedtii* and *Huso huso*). *Salmo caspius* (Caspian trout) is the most important species in the upper reaches. Cyprinoid species found in this river include *Alburnoides bipunctatus* (*sic*, but this river is the type locality of *Alburnoides tabarestanensis*), *Alburnus chalcoides*, *Alburnus* sp. (presumably *Alburnus hohenackeri*), *Barbus lacerta* (= *B. cyri*), *Capoeta capoeta gracilis* (= *C. razii*) (dominant at 52.3% abundance), *Carassius auratus, Ctenopharyngodon idella*, *Cyprinus carpio, Hypophthalmichthys molitrix, Luciobarbus capito, L. mursa*, *Pseudorasbora parva*, *Rutilus kutum, Rutilus rutilus (= R. lacustris*), *Squalius cephalus* (= *S. turcicus*), *Vimba vimba* (= *V. persa*). Sharifinia *et al*. (2012) used benthic invertebrates and biotic indices to assess the ecological status of the Tajan River and found lower water quality below fish farms and a factory effluent. Zazouli *et al*. (2013) examined water quality at 10 stations on a monthly basis and found pH (6.5-8.5) and temperature (>20ºC) were within acceptable ranges, minimum dissolved oxygen was above 6 mg/l, acceptable to fish, and the maximum levels of other parameters such as biological oxygen demand (30 mg/l), chemical oxygen demand (17 mg/l), phosphate (0.5 mg/l) and nitrate (0.7 mg/l) were at or below acceptable levels. Saravi (2015) studied the macro-invertebrate community and physico-chemical indices at six stations along 80 km of this river to assess water quality and found reduced dissolved oxygen and increased total dissolved solids, nitrate and ammonium at various stations. Shokri *et al*. (2015) investigated water quality in the Tajan River using the population structure of benthic macro-invertebrates and found half of six stations were not in an appropriate condition qualitatively. Ebrahimi *et al*. (2018) assessed water quality in this river and found it to range from medium to very bad. Sedighkia *et al*. (2021) proposed and evaluated a fuzzy hydraulic habitat simulation-genetic algorithm method to optimise the environmental flow regime of the Tajan with focus on a projected diversion dam.

The most important advantage of the method was to minimise conflict between stakeholders and environmental advocates. The main fish concern was *Salmo caspius* habitat as this species is protected by the Department of the Environment and is on the Red List of the International Union for Conservation of Nature. Naturally, cyprinoids would also be affected.

Agricultural and industrial pollutants are found in the Tajan and affect the fishes along with dams and other physical obstacles, sand and gravel removal (Roshan Tabari *et al*., 2011) and overfishing. Ebadi and Zare (2005) studied levels of the insecticide parathion in flesh of *Rutilus kutum* and *Vimba persa* (along with the clupeid *Clupeonella delicatula* (= *C. caspia*, common kilka) and *Liza aurata* (= *Chelon auratus*, golden mullet)) and found levels were safe for human consumption. Ahmadi-Mamaqani *et al*. (2011) found that the pesticide diazinon persisted in the river for a period that could have severe undesired effects on fishes. Zare and Ebadi (2005) measured heavy metals (cadmium, copper, lead) in *Rutilus kutum* from this river and found no threat to the fishes and public health. Ebadi and Hisoriev (2017) examined the whole river for heavy metal pollution and found levels were within reference guidelines for surface water quality standards.

Mazandaran, Tajan River in Sari
(CC BY-SA 4.0, Ahmadrizo).

Mazandaran, Tajan River, Hamid Reza Esmaeili.

The Shahid Rajaei, Rajaee or Rajai Dam, or Soleyman Tongeh Dam, inaugurated in 1997, is found on the Tajan River 41 km south of Sari. Sharghi *et al*. (2011) found that the dam had major effects on biological, chemical and physical properties of the river. *Capoeta capoeta gracilis* (= *C. razii*) and *Alburnoides bipunctatus* (*sic*, but the Tajan River is the type locality of *A. tabarestanensis*) were the most abundant fish species but only a single specimen of *Luciobarbus capito* was caught in over a year of sampling (2008-2009). Shoaei *et al*. (2014) showed that water in this dam had levels of cadmium and lead above acceptable amounts, from fertilisers and pesticides, and possibly natural sources. Nasrollahzadeh Saravi *et al*. (2017) found dam water to be eutrophic and moderately to highly-polluted in July and August. Shakeri *et al*. (2015) found levels of chromium were higher than World Health Organisation standards in *Squalius cephalus* (= *S. turcicus*) and a barbel species, and mercury and nickel in the barbel species in this dam. Various other heavy metals and organic pollutants were detected in the dam water, especially from application of fertilisers and pesticides to paddy fields. The maximum allowable fish consumption for arsenic was two meals per month, for mercury 1-3 meals per month and for pesticides one meal per month. The *Independent* (London) reported on 13 July 1994 that tens of thousands of fish died in the Tajan River after poachers poured poison into it about 9 miles (= 14.5 km) above the estuary. Dead fish covered the river bed for 6 miles (= 9.7 km).

Rafiee and Yazdani (2016) studied the feasibility of re-designing traditional bony fish markets in Mazandaran because of consumer and fishermen dissatisfaction with unfavourable market conditions and high prices. Assadollahpoor *et al*. (2018) investigated the behaviour of consumers at fish markets and the demand for fish in Mazandaran, the main rivers of which being described above.

Mazandaran, Shahid Rajaei Dam
(Shahid Rajayi Dam 25837656938, CC BY 2.0, #IranOpenAlbum (Negar Ghaffari)).

The south-eastern corner of the Caspian Sea receives three major rivers, the Gorgan and the Qareh Su, and the Atrak or Atrek (Classical Sarnois). These receive their waters from the rain shadow of the eastern Elburz Mountains. A stream in the Atrak River basin is the type locality of *Alburnoides parhami* (= *A. holcik*i).

Southeastern Caspian Sea, Turkmenistan and Iran, with green of Elburz Mountains and phytoplankton bloom in the sea (red dots are fires) (CC0, NASA).


Gorgan and Qareh Su River basins
(IranCatchMaz6, CC BY-SA 4.0, Mahdy Saffar).

Their courses are roughly east-west and parallel each other with the Atrak forming part of the border with Turkmenistan. The Gorgan River (Wolves River) is 240 km (350 km in the Encyclopædia Iranica).


Golestan, Gorgan River at Bibi Shirvan village (CC BY-SA 4.0, Rrrahmatt).

The Gorgan River drains 10,200 sq km and has an average discharge of 9.39 cu m per second (*cf*. Sefid River with 182.17 cu m per second; the Chalus River, directly north of Tehran, has a discharge of 12.65 cu m per second). Keivany *et al*. (1990) reported an irregular pH range for the Gorgan River from 6.3 to 7.9 with an average of 7.1. Temperature range was 8 to 33°C. Conductivity varied greatly from 667 to 10,000 µM/cm, with an average of 875 µM/cm. Chlorides, especially sodium chloride, were the most abundant soluble salts. Total dissolved solids varied from 21 mg/l to 4,300 mg/l in an inverse relationship with water volume. Oloomi (2001) described the benthic and phytoplankton fauna and flora and noted fish density was highest in the lower reaches of the river, particularly in the spawning season with *Cyprinus carpio*, *Rutilus rutilus* (= *R*. *lacustris*) and *Rutilus kutum*. Banadani *et al*. (2020) investigated the size and numbers of fingerlings of *Cyprinus carpio* and *Rutilus caspicus* (= *R. lacustris*) released in the Gorgan River, decline of the water level in the Caspian Sea and discharge of the river on catch per unit effort of the two species from 1999 to 2017. During the last four years, the catch share of *C. carpio* and *R. caspicus* in Golestan Province decreased in comparison to the total catch rate of these species in Iranian waters of the southern coast, while the number of releases in these four years increased. Sea level decline, released weight and released numbers simultaneously affected the rate of catch per unit effort. Alijani *et al*. (2016) analysed stream flow in the Gorgan River over a 30-year period (1980-2010) and documented severe shortages which appeared with greater frequency at the end of the study period. Rouhani and Sadat Jafarzadeh (2018) modelled climate change in the Gorgan River basin and found simulations projecting average autumn total flow declines of ~10% and an overall average range of 6.9-13.2%.

The Voshmgir, Gorgan or Sangarsavar Dam at 37°12'N, 54°45'E on the Gorgan stores 60 million cu m of water. The water level fluctuates markedly, banks are steep and there is little emergent vegetation. The Golestan Dam is 20 km north of Gonbad-e Kavus on the Gorgan River and has a capacity of 86 million cu m. Water volume at the Gorgan Dam inlet varied from 2 to 75 cu m/second and almost 52% of the sediments entered the dam during a high flood (Keivany, 1990). Water quality was assessed as polluted. The major fish species were *Cyprinus carpio*, *Barbus barbus* (*sic* - possibly *Luciobarbus capito*), *Alburnus* spp., *Cobitis taenia* (Cobitidae, presumably *C. keyvani*), *Gambusia affinis* (probably *G. holbrooki*, eastern mosquitofish), and *Carassius carassius* (probably *C. auratus*). Poursoufi *et al*. (2020) outlined the biological condition of the dam based on primary production, and estimated fish production potential of the lake (203.49 kg/ha) with the catch (142.9 kg/ha), concluding that the production power models used had a good estimation of the actual production capacity of the lake. Mansouri *et al*. (2021) described changes in physicochemical factors and noted the dam is oligotrophic. Rostamian *et al*. (2015) described the physico-chemical parameters of the Node Khanduz, Seyed Abad and Marzban dams in Azad Shahr, Gorgan which showed surface temperatures up to 33C in June and July, among other parameters.

A fish kill noted by Coad (1980b) in 1978 was attributed by local informants to careless insecticide spraying on fields neighbouring the Gorgan. Newspaper and radio reports variously stated that 200 barrels of a highly toxic chemical spilled into the river when a truck overturned and that the chemical, identified as turbidan from the Trintext chemical plant, was dumped by a technician commissioned to get rid of the waste product (*Kayhan International*, 7 May 1978). Bagheri (2007) gave details of pesticide residues in the Gorgan and neighbouring Qareh Su rivers. Zoriasatain (2008) and Zorriasatein *et al*. (2009) showed that water quality in the Gorgan River was good to fair upstream but poor at all downstream sites. Tabari *et al*. (2012) measured the heavy metals cadmium, chromium and lead in water from 10 stations on the Gorgan River and found concentrations were below recommended thresholds. Baghfalaki *et al*. (2013) examined surface waters of the Gorgan River estuary and found higher levels of the insecticide malathion in spring, with decreasingly lower levels in summer, autumn and winter. Spring and summer levels were higher than permissible, as a result of timing of insecticide application.

Tedesco *et al*. (2013) listed the Gorgan basin as one of 20 basins out of 1,010 studied likely to suffer the greatest biodiversity loss due to water availability shrinkage from climate change.

Aquaculture of common and Chinese carps takes place in earthen ponds in the Gorgan River basin with water pumped from the river. An environmental impact assessment of one set of ponds in the Digche region was carried out by Khoshbavar Rostami (2016).

Habitat of *Alburnus hohenackeri* and *Capoeta razii*, CMNFI 1979-0480, Golestan, Gorgan River at Gonbad-e Kavus, note sand removal, 6 July 1978, Brian W. Coad.

The Qareh Su (= Gharesoo, Gharasou, Gharasu, Gharesou, Qarasu) is another river entering the Gorgan Bay or Talab. It is 160 km long. In its upper reaches it has a rocky bed and a fauna of *Paracobitis malapterura* (Nemacheilidae), *Alburnoides cf. bipunctatus* (*sic*, presumably *A. tabarestanensis*) and *Capoeta capoeta* (= *C. razii*), resembling the grayling zone of Europe. The central part of the river dries up (the barbel zone) while the lower river (bream zone) is brackish from Caspian Sea input, has high temperatures and pollution. This lower zone has *Alburnus alburnus* (= *A. hohenackeri*), *Carassius auratus*, *Cyprinus carpio*, *Pseudorasbora parva*, *Gambusia holbrooki* (eastern mosquitofish) and *Gasterosteus aculeatus* (threespine stickleback) with *Atherina boyeri* (= *A. caspia*, Caspian silverside), the gobies *Neogobius kessleri* (= *Ponticola gorlap*), *Neogobius melanostomus*, *Neogobius pallasi* and *Knipowitschia caucasica*, and *Liza saliens* (= *Chelon saliens*, sharpnose mullet) feeding in the estuary, and the sturgeon *Acipenser stellatus*, *Alburnus chalcoides*, *Cyprinus carpio*, *Rutilus rutilus* (= *R. lacustris*) and *Vimba vimba* (= *V. persa*) migrating into the river for reproduction.

Ahmadi *et al*. (2015) analysed consumption of aquatic foods in Golestan Province in the southeastern part of the Caspian Sea basin. Average per capita consumption was 9.65 kg/year in urban areas and 8.35 kg/year in rural areas, inflation and lack of shopping malls near the workplace and residence being the main obstacles to a greater level of consumption. Aliabadi *et al*. (2015) found that that all consumers in Gorgan City (based on 284 households) had a favourable idea about wild fish especially in taste, odour and nutritional value, and they knew wild fish better than farmed fish. Aghili *et al*. (2019) questioned 343 families in Gorgan City and found preference for fishes from the Caspian Sea, warm water and cold water. Factors such as quality, freshness and price had the most important role in purchase decisions. About 39.5% of Gorgani families preferred to buy packaged aquatics. A lack of confidence in freshness and health of aquatics, having enough time, and their higher prices were the main reasons for the use of packed production. 58.4% of consumers preferred to buy from fishery agencies.

The Atrak River headwaters are close to those of the Hari basin. The Atrak basin comprises about 40,000 sq km. The Atrak is 495 km long (with 145 km of this in Turkmenistan; Nezami *et al*. (2000) stated 715 km for the Atrak and the Encyclopædia Iranica 545 km (www.iranicaonline.org/, downloaded 10 July 2016). Stream flow in the Atrak River basin has shown a downward trend over a 35-year period from 1971 with precipitation, land use and increased evapotranspiration due to higher temperatures as possible factors (Sheikh and Bahremand, 2011; Sheikh, 2013). The Atrak is only about 10-15 m wide and about 0.5 m deep over much of its lower course. It only reaches the Caspian Sea during floods. A tributary of the Atrak from Turkmenistan is the saline Sambar River, about 203 km long. Petr (1987) reported that efforts were being made to divert this river so as to increase the water quality in the Atrak. The fresh section of the Atrak has a conductivity of 2,362 µS and the saline section 23,500 µS. The Caspian Sea off the Atrak River is an important fishery economic zone. Gasan-kuli or Hasan Kuli is a town in Turkmenistan near the Iranian border referred to in fishery reports from this area. The catch of *Rutilus caspicus* (= *R. lacustris*), *Cyprinus carpio* and *Sander marinum* (sea pike-perch) was nearly 1.44 x $10^4$ tonnes with only 1.9% being accounted for by the clupeid *Clupeonella cultriventris* (= *C. caspia*, common kilka). However, by 1972, the catch of the commercially important species had declined to 1.5% and the less desirable *Clupeonella* had increased to 5.73 x $10^4$ t or 98.3% of the catch. The causes were reduction in the Atrak runoff through irrigation withdrawals, pollution from agriculture, overfishing in the sea and the drop in sea level. Flows of the Atrak did not reach the sea in 1984, 1986, 1990 and 1991and spawning of species using the lower reaches did not occur (Caspian Environmental Programme, 2000).

Atrak River basin
(IranCatchMaz7, CC B Y-SA 4.0, Mahdy Saffar).

Razavi Khorasan, Atrak River headstream
(CC BY-SA 4.0, Ali. N. Sani).

North Khorasan, Atrak River (CC BY-SA 4.0. lightened, Afshin230).

There are five lakes along the Atrak, fed by the river, which have been recently dyked to improve water retention. Their fauna is dominated by native cyprinoids. The lowest lake is saline and they range in size from 400 to 2,500 ha. The lakes Alagel (*sic*, after the U.S. Board on

Geographic Names, but logically the following name incorporating “gol” for lake is correct and is used herein), Alagol or Ala-Gol at 37°21-22'N, 54°35'E, Ulmogol, Alma-Gol or Ulmagol 37°24-25'N, 54°38-39'E and Ajigol or Adji-Gol at 37°24-25'N, 54°40'E comprise a Ramsar Site (World Conservation Monitoring Centre, 1990; Scott, 1995; Mirabzadeh-Ardakani, 2014) near the frontier with Turkmenistan just east of the Caspian Sea. Alagol occupies 900 ha (Scott, 1995) to 2,500 ha (Sedaghat and Hoseini, 2012), Ajigol 360 ha and Ulmogol 280 ha (Scott, 1995). The Alagol Lake is slightly saline with a mud and sand bottom. It is fed by springs, seepage and precipitation and may dry out completely in summer. It overflows westwards when full. Vegetation is sparse with *Juncus*, *Carex* and grasses mainly in the northeast and small patches of *Phragmites communis*. It is oligotrophic and vegetation poor. Sedaghat and Hoseini (2012) gave yearly ranges in values of 10.16-26.9ºC, pH 7.88-8.94, conductivity 5.17-6.71 µS/cm, dissolved oxygen 5.95-9.9 mg/l, biological oxygen demand 3.0-4.66 mg/l, salinity 4.33-6.0 mg/l and turbidity 26.66-33.33 NTU (Nephelometric Turbidity Units). The other two lakes have seasonal fresh water fed by precipitation and have a mud and clay bottom. They are eutrophic and water levels vary greatly so that they may dry up completely. Ulmogol has little vegetation such as *Juncus*, the duckweed *Lemna*, *Phragmites communis*, *Alhagi* and algae while Ajigol has extensive *Phragmites* reedbeds at its eastern end and abundant submerged vegetation. Fishing occurs in the lakes and the habitats are affected by cattle grazing and reed cutting. Water is abstracted for irrigation and for a fish hatchery. In Alma-Gol (= Ulmogol) and Alagol, 90.91% and 82.18% of the total frequency of fishes was comprised of exotic species. *Hemiculter leucisculus* was the most frequent in Ulmogol (58%) and Ajigol (16.82%) and *Carassius auratus* in Alagol (77.6%). Other exotics were *Gambusia holbrooki* (eastern mosquitofish), *Pseudorasbora parva* and *Cyprinus carpio* (Patimar and Kiabi, 2005; Patimar, 2007). Patimar (2008) detailed the environment of these lakes and listed six native species (*Alburnus alburnus* (= *A. hohenackeri*), *Barbus* (= *Luciobarbus*) *capito*, *Capoeta capoeta* (= *C. razii*), *Cyprinus carpio*, *Rutilus rutilus* (= *R. lacustris*) and *Atherina boyeri* (= *A. caspia*, Caspian silverside) and four introduced species (*Carassius auratus*, *Hemiculter leucisculus*, *Pseudorasbora parva* and *Gambusia holbrooki* (eastern mosquitofish)), variously distributed among the lakes. The decapod crustacean *Macrobrachium nipponense* was also introduced into Alagol Lake (Gorgin and Sudagar, 2008).

Incheh Borun Lake at 37°13'N, 54°30'E is a small and isolated freshwater body of 50 ha about 40 km north of Gorgan. Lake Bibishervan at 37°09'N, 54°52'E and Lake Eymar at 37°08'N, 54°52'E are two more small isolated freshwater lakes occupying 300 ha and 250 ha respectively. All three lakes lie on a cultivated plain, part of the Turkoman steppe near Gonbad-e Kavus.

The lakes above, along with the Daneshmand and Namak lakes, are called the Aq Qala Wetland Complex and are illustrated below.

Golestan, Aq Qala Wetland Complex
(CC BY 4.0, *Tasnim News Agency*, 19 February 2019).

The Golestan National Park lies between Bojnurd and Gonbad-e Kavus and is divided by the Tehran-Mashhad highway. The *Iran Nature and Wildlife Magazine* (volume 3, 1999; downloaded from its English website) stated that fish in the Dogh River included *Oncorhynchus mykiss* (rainbow trout) and *Umbra krameri* (*sic*, Umbridae, a European species), both exotics. The latter species is an error of translations from Farsi to English of common names (B. Kiabi, pers. comm., 23 February 2000). A description of the park was given by Kiabi *et al*. (1994) and

of the Madar Su Stream in the park, which has been studied ichthyologically, by Mikaeili *et al*. (2005). Panahi *et al*. (2010) documented increased floods in the Madar Su from 1960 to 2002 as natural land decreased and agricultural land increased. Karami and Mahmoodi (2008) evaluated water quality of rivers in the Gorgan River catchment including the Dogh River. Flood values were better than base values, and the sample localities of the Dogh River, upstream of urban areas, were less polluted than those downstream.

The Anzali (= Enzeli or Pahlavi) Mordab or Talab (37°26'N, 49°25'E) is a freshwater to brackish lagoon or wetland (Firouz, 1968b) separated from the Caspian Sea by a sandy barrier about 1 km wide. Anzali is the type locality for *Cyprinus bulatmai*, *Cyprinus chalybeus* and *Cyprinus chalybatus* (all = *Luciobarbus capito*). It may be referred to variously as a talab, wetland, marsh or lagoon herein. This water body is surrounded by ab-bandans such as the Selke Ab-bandan of 360 ha at 37°24'N, 49°29'E which is protected as a Wildlife Refuge. Ab-bandans are a feature of the Caspian coastal plain, being a shallow and artificial freshwater impoundment managed in winter for duck hunting and in summer as an irrigation reservoir. Safaian and Shokri (2003) described ab-bandans in Mazandaran based on 423 of these features and Khorasani and Rokni (2001) examined two Mazandaran ab-bandans in particular. The Anzali Talab complex of 15,000 ha is a Ramsar Site and this includes the whole talab, the Siahkeshim marshes, Selke Ab-bandan and several other ab-bandans. The main talab comprising open water is 26 km long and 2.0-3.5 km wide encompassing about 11,000 ha. Reed beds extend the eastern limit by a further 7 km. The environmental ecology for fish was reviewed by Nasrollahzadeh (2021).

Talaei and Daryadel (2015) reveiwed the environmental challenges facing the lagoon, but also examined and analysed legal and non-legal mechanisms to resolve such issues in the framework of the Ramsar Convention. These mechanisms included, but are not limited to, realisation of sustainable development, environmental impact assessment, wise use of wetlands, and ecosystem-based approaches.

The ichthyodiversity of the talab and its related rivers was summarised by Abbasi *et al*. (2019). The fishes comprised 72 species in 21 families with 66 species in the talab or wetland and 53 species in the rivers. Thirty-four species were resident in fresh water, nine species were anadromous, nine species were estuarine and the rest lived in different habitats. Four species were Iranian endemics, 50 were native and 18 were exotics. Cyprinoids dominated the wetland and rivers. The Cyprinidae comprised five native species (*Barbus cyri*, *Capoeta razii* (endemic), *Cyprinus carpio, Luciobarbus capito*, *L. caspius*) and two exotics (*Carassius auratus* and *C. gibelio*; and presumably some *Cyprinus carpio* are exotics too) and the Leuciscidae comprised 14 species (*Abramis brama*, *Alburnoides samiii* (endemic), *Alburnus chalcoides*, *A. filippii*, *A. hohenackeri*, *Blicca bjoerkna*, *Leucaspius delineatus*, *Leuciscus aspius*, *Pelecus cultratus*, *Rutilus kutum*, *R. lacustris*, *Scardinius erythrophthalmus*, *Squalius turcicus*, *Vimba persa*). Most cyprinoids were freshwater residents or potamodromus. *Alburnus chalcoides*, *Luciobarbus caspius*, *Pelecus cultratus*, *Rutilus kutum* and *Vimba persa* were classified as anadromous, living in the Caspian Sea and migrating to the wetland and adjacent rivers for spawning. *Abramis brama*, *Cyprinus carpio*, *Leuciscus aspius* and *Rutilus lacustris* were classified as semi-anadromous, found in all regions and needing fresh water for spawning. Abbasi *et al*. (2021) listed *Abramis brama* and *Luciobarbus capito* in the endangered category and *Leuciscus aspius*, *Luciobarbus caspius* and *Pelecus cultratus* in the least concern category in this lagoon. Mirzajani (2009) noted the highest and lowest fish catches were 640 and 288 t in 1994 and 1999 respectively in their 1990 to 2003 study period and was about 500 t at the end of the study.

Hajiaghaei Ghaazi Mahalleh and Imanpour Namin (2021a) gave an overview of the fish

of the Anzali Wetland noting that it acts as a natural reproduction and rehabilitation ground for several groups of fish from the Caspian Sea and also serves as a habitat and spawning ground for the Caspian Sea migratory fish during their early life stages. Fishes of the Anzali Wetland have economic, commercial, environmental or protective, recreational and sports fishing values. Populations of many of these fish species have severely declined and are placed in endangered categories (vulnerable, highly endangered and critically endangered). Hajiaghaei Ghaazi Mahalleh and Imanpour Namin (2021b) investigated threats to the wetland and recorded decreased water level, rapid growth and distribution of macrophytes like *Typha* (reeds) and *Azolla*, especially in the warmer months, heavy erosion in the catchment area and increased sediment inputs to the wetland, conversion of wetland margins to agricultural lands, heavy motorboat traffic and the creation of motorboat areas, increased hunting pressure on waterfowl, increased levels of heavy metals and especially lead in water and sediments, pumping water upstream of the wetland mainly for rice field irrigation, construction of fish ponds around the wetland, construction of canals to transfer water upstream, and changes in physical and chemical properties of water all of which have affected the spawning and reproduction success of commercial fish. Further data is given below.

Sadeghinejad and Abbasi (2021) studied the effect of sediment ponds on fish diversity in this wetland from summer 2014 to spring 2015 in 14 stations. The results based on 6,757 specimens and 2,763 measured ones showed three exotic species (*Carassius gibelio*, *Gambusia holbrooki* (eastern mosquitofish) and *Hemiculter leucisculus*) constituted about 63.6% of the total fish number. Three large-sized fish species (*Cyprinus carpio*, *Esox lucius* (northern pike) and *Ctenopharyngodon idella*) has the highest biomass but low abundance (4.2% of numbers). The Simpson dominance and Shannon diversity indices were determined for 14 species, and were 0.54 and 2.11 for the lower station of the Pasikhan River sediment pond and for 16 species were 0.77 and 1.94 for the upper station on the sediment trap. Simpson dominance and Shannon diversity indices were calculated for 14 species, 0.53 and 2.13 for the lower station of the Siahdarvishan River sediment pond and for 16 species, 0.72 and 2.23 for upper station on the sediment trap. The sediment traps have an important role in depletion of silt and clay entering into the wetland, and are a new habitat for some fish species, but they have no distinct effect on the number of fish species and diversity indices.

Abbasi *et al*. (2021) noted that more than 15 small rivers enter the wetland and the Masuleh-Rukhan River is one of the most important ones. The river has its origins in the Masuleh Mountains and joins downstream to the Siahdarvishan River near the Siahkeshim Protected Region. Sampling of fish species was done seasonally in seven stations from upstream to downstream in 2016. The results showed 20 fish species with *Capoeta razii*, *Ponticola iranicus* (Gobiidae), *Alburnoides samiii*, *Cobitis saniae* (Cobitidae) and *Rhodeus caspius* with relative abundances of 30.3, 27.3, 25.4, 3.2 and 1.1% respectively, accounting for totally 87.2% of individuals. 12 fish species were native and constituted 11.1% of individuals, five fish species were alien and their total abundance was 1.7% of the total fishes. 0.3% of the total population belonged to three migratory (anadromous) fish species (*Alburnus chalcoides*, *Rutilus kutum* and *Vimba persa*) and the low abundance of these showed some problems for migration and natural spawning of Caspian Sea anadromous fish species from this river.

Abbasi *et al*. (2021) examined the Pir Bazar River, one of the larger and more polluted rivers entering the wetland. It has two tributaries, the Gohar and Siah (Zarjoob) rivers. Sampling was done seasonally in the upstream Gohar and Siah tributaries and the downstream Pir Bazar River from Pir Bazar town to the confluence with the Pasikhan River in 2016. The results

showed nine fish species lived in the Gohar tributary and *Alburnoides samiii*, *Capoeta razii* and *Ponticola iranicus* were dominant with 35.2, 30.0 and 29.3% of individuals, respectively. There were 13 species in the Siah tributary and *A. samiii*, *P. iranicus*, *Cobitis saniae* and *C. razii* were dominant with 43.0, 21.6, 16.8 and 14.3% of individuals, respectively. There were 10 fish species in the downstream Pir Bazar River and *Pseudorasbora parva*, *Gambusia holbrooki* (eastern mosquitofish) *Carassius gibelio* and *Alburnus chalcoides* were dominant with 27.3, 16.0, 14.8 and 11.2% of individuals, respectively. This study showed suitable diversity and dominance of fish species in the upstream Pir Bazar River basin with very low pollution. However, diversity and specific abundance of fish species was low in the downstream Pir Bazar River owing to a high pollution load.

Zazanashvili *et al*. (2020) listed this wetland as important for fish conservation in their Ecoregional Conservation Plan for the Caucasus.

The oriental river shrimp (*Macrobrachium nipponense*), an exotic species, obtained 16.8% of its food from fish in the talab and was at the top of the food web, close to commercially important fish species such as the pike, *Esox lucius*. Moghaddas *et al*. (2020) provided a risk assessment for the potential invasiveness of the cichlid *Coptodon zillii*.

Hydrorybproject (1965), Kimball (1973), Kimball and Shayegan (1973), Kimball and Kimball (1974), Hagh-Panah (1992), Holčík and Oláh (1992), Caspian Environmental Programme (2001c), Japan International Cooperation Agency (2005), Mirzajani (2009), Abedini (2017) and Fallah *et al*. (2021) gave details of the limnology of the Anzali Wetland. Water temperatures varied seasonally from 0° to 28.8°C (average about 16ºC) and dissolved oxygen from 0 to 17.5 mg/l, for example. Phytoplankton blooms have killed fish in the talab, e.g., on 5 June 1997, when dissolved oxygen in the western part was at 0-0.2 mg/l and hydrogen sulphide was at 2.0-2.5 mg/l (*Iranian Fisheries Research and Training Organization Newsletter*, 17:7, 1997). Conversely, low phytoplankton populations have probably resulted in lowered fish catches. High water temperatures and chlorophyll inactivation through high light levels reduced the numbers of phytoplankton and hence zooplankton, on which fish fed, also declined.

The Siahkeshim (or Siah-Kesheem) Protected Region within the marsh has a lagoonal surface area of 4,500 ha (Khara, 1994; 6,700 ha in Scott, 1995) and is about 12 km long by 4.5 km wide. It lies to the southwest of the main talab, of which it was probably once part, and is fed by the Esfand River. Note that Khan *et al*. (1992) stated that the Anzali Talab is unprotected except for the Siahkeshim Protected Region and the Selke Ab-bandan of 360 ha. A description of the Siahkeshim Protected Area was given by Riazi (1996) and of the wetland generally by Monawari (1990) and Bagherzadeh Karimi (2018). Pollution in the Siahkeshim Wetland was reviewed by Ganjidoust *et al*. (2009). Important fishes were listed as *Sander lucioperca* (pike-perch), *Cyprinus carpio*, *Silurus glanis* (European catfish) and *Esox lucius* (northern pike) (Iran Nature and Wildlife Magazine, 5, www.neda.net/inwm/no.5/english/pre_sites/pre_sites01.html, downloaded 8 March 2000). Fallahi Kapourchali (2018) described aquatic communities and their changes in this wetland over a one-year period.


Gilan, views of Anzali Talab near Bandar Anzali: left 24 August 1974, Neil B. Armantrout; right 11 April 2005 (Anzali (Iran)- Lagoon-CaspianSea, CC0, Hara 1603).

Ashoori *et al*. (2017b) found that three of four ardeid species (black-crowned night and squacco herons and cattle and little egrets) in the Anzali Wetland fed on Cyprinoidei in relative abundance of 58.5%, 48.3%, 0% and 17.1%.

The main talab is drained by the Sowsar Roga, Pir Bazar Roga, Raste-Khaleh (presumably Rasteh Kenar) Roga, Nahang Roga and Pahlavi or Koulivar (presumably Kolver) Roga over a distance of about 4 km to the Caspian Sea (a *roga* is an outflow; in **Distribution** records herein they are regarded as rivers and roga is not included in the name). Warm, dense and saline sea water is able to penetrate up these effluent rivers for as much as 10 km because of the rise in sea level since 1977, and these rivers generally have low flow because of water abstraction and seasonally low precipitation. Fresh water flows across the surface of the saline water mixing at depths of 0.5-2.0 m. Salt water contamination is always a danger as more water is abstracted in this heavily populated and farmed area (Kimball, 1973; Kimball and Shayegan, 1973; Sharifi, 2005, 2006). Sharifi (2005) noted a depth-dependent salinity gradient penetrating up to 10 km into the wetland, and the greatest loss of water quality occurs where polluted effluent coincides with penetration of saline water.

Gilan, Pir Bazar Roga, ca. 1885 to ca. 1910 (CC0 1.0, Rijksmuseum, Amsterdam).

Gilan, Bandar Anzali Port, February 1925
(CC0, cropped and sharpened, ETH-Bibliothek, Walter Mittelholzer).

Abdolmaleki (1994) gave some data on the benthic macrofauna of this lagoon. Hosseinpour (1995) surveyed the zoobenthic resources of the Siah Darvishan and Pasikhan, two principal rivers which enter the lagoon. Other entering rivers are the Bohambar, Chakoor and Esfand. Asadi (2016) estimated sediment, organic carbon and phosphorus loads in the Pasikhan River. The sediment load had increased and other levels also indicated soil erosion was an important problem in the watershed. Very high loads of phosphorus and organic carbon resulted

in eutrophication of the Anzali Wetland. Abedini (2017) recommended decrease of nutrient components from inlet rivers and removal of aquatic plants in the wetland to control this eutrophication process. Jafari (2009) reviewed the ecological integrity of this wetland and Björk (2014) discussed limnological methods for restoration. Ayati (2003, 2016) reported on sanitary and industrial wastewater effects on the wetland. Fazel and Tanimoto (2012) produced an ecological management plan for the wetland with occasional mention of fish and fishing. Fallah and Isfahani (2016) investigated land use around the wetland from 1985 to 2014 using a Geographic Information System and showed that most forested land was replaced by fields and urban areas with consequent effects on water quality. Fallah and Zamani-Ahmadmahmoodi (2017) assessed water quality in the wetland over a 29-year period and found that eastern stations were of lower water quality (very poor) than central and western ones from industrial and agricultural wastes. Homami *et al*. (2017) estimated water quality changes in the Pir Bazar River, predicting the mean annual concentration of ammonium, nitrate, nitrite, phosphate and dissolved salts would increase by 1.2%, 3.2%, 32%, 5% and 7% by 2020 and 3.4%, 9%, 87%, 14% and 16.5% by 2030. Rahimi *et al*. (2018) found the water quality of the Khalkai River, which enters the wetland, was adversely affected by rainbow trout (*Oncorhynchus mykiss*) farms. Forest clearance around the talab, rice production and other agriculture, dams and weirs on inflowing rivers, river bed erosion through decline in Caspian Sea level, influx of pesticides such as diazinon (Talebi, 1998), paraquat, glyphosate, and chemical fertilisers, domestic and agricultural sewage, excessive aquatic plant growth, and natural decay of vegetation (Nezami and Khodaparast, 1996; Filizadeh and Khodaparast, 2005), phytoplankton blooms, some toxic (Nejatkhah *et al*., 2003), anionic surfactants (Dadaye Ghandi *et al*., 2005), siltation from deforestation of feeder streams, sediment and sludge accumulation (1-7 mm/year, 3 m depth decrease in the past 30 years) from five neighbouring cities, introduction of exotic species of fish and plants such as *Azolla* (*Iran Daily*, 2 November 2006; *Tehran Times*, 11 April 2017, 9 July 2019), grazing for livestock, reed cutting for mats, fences and building materials, and a high urban population growth of 4.6% per year, all affected the habitat and the marsh was highly eutrophic or super eutrophic (Mirzajani *et al*., 2010; Abedini *et al*., 2018). These factors also contributed to the fall in commercial fishing success. In the 1930s the catch was dominated by the valuable *Rutilus frisii kutum* (= *R. kutum*) but in the 1990s the catch was 50-75 times lower and the talab now had a low value to fisheries. The situation was compounded by the absence of effective fishery management. The introduced *Carassius auratus* dominated catches (38.46% in a study by Moradinasab *et al*. (2012) with 34.92% *Esox lucius* (northern pike), 18.94% *Cyprinus carpio*, 5.28% *Hypophthalmichthys molitrix* and 2.4% *Ctenopharyngodon idella*). The talab was a principal breeding ground for *Rutilus frisii kutum* (= *R. kutum*), *Abramis brama* and *Cyprinus carpio*, and to a lesser extent *Sander lucioperca* (pike-perch), and was an important habitat for *Esox lucius* (northern pike). Fish kills occurred, more than 100,000 dying in August 1997 due to a lack of oxygen after torrential rain and the growth of aquatic herbs had created an unsuitable environment (a Reuters report) and more fish died in 2005 (*Iran Daily*, 21 August 2005). Ghahraman and Atar (2003) concluded that the wetland was dying.

The bottom of the shallow west basin was completely covered by perennial submerged vegetation in the early 1970s (*Ceratophyllum*, *Chara*, *Hydrilla*, *Myriophyllum*, *Nitella* and *Vallisneria*). Water chestnut (*Trapa natans*) was the predominant floating plant and covered the central basin in 1966. The Caspian lotus, *Nelumbium caspium* was found all across the lagoon and was a significant part of the standing stock. *Phragmites*, *Sparganium* and *Typha* were emergent plants which engulfed open water. Reeds were formerly cut extensively for building

purposes but are now replaced by sheet metal and cement blocks. Falling Caspian Sea water level and eutrophication from domestic sewage and fertilisers aided plant growth. The fern, *Azolla filiculoides*, was introduced as an additive to cattle feed and rice cultivation from the Philippines in 1986. It soon entered the talab from the rice fields and mats up to 20 cm thick covered much of the open water in 1991 (Holčík and Oláh, 1992; Filizadeh, 2002; Dadjouy, 2012). The water hyacinth, *Eichhornia crassipes*, one of the fastest growing plants known, has also been introduced and measures to remove it failed (*Financial Tribune*, 31 January 2016; Khodabakhsipour and Ghasemi Zolpirani (2021)). Dense growths of macrophytes have contributed to declines in commercial fish catches as spawning grounds have decreased, eutrophication was enhanced, and light penetration was decreased and so oxygen declined.

There are about 200 sq km of marshes and 30 sq km of shallow open water fed by rivers from the Alborz Mountains. The area of open water in 1989 was only 22.5% of that in the late 1930s (Holčík and Oláh, 1992). However, the rise in Caspian Sea level since 1978 led to a salt water intrusion during the summer months when the Caspian level was at its highest and freshwater input from rivers was at its lowest. Deeper and more saline water may well inhibit plant growth in the future (Khan *et al*., 1992).

The marsh is only a few metres higher than the Caspian Sea and had a maximum depth of 2.5 m in the early 1970s. Caspian Sea level fluctuations have serious effects on the level of the talab and hence its utility as a habitat for fishes. The optimum level for the fish industry in general in the Caspian basin was given as -27±1 m (Mandych, 1995). The rise in Caspian Sea level since 1977 was gradually returning the talab to its supposed, natural brackish state and may improve the fisheries situation which had declined over 50 years. Emergent and submergent aquatic macrophytes decreased and such fish as *Atherina boyeri* (= *A. caspia*, Caspian silverside), *Alosa caspia* (Caspian shad), *Liza aurata* (= *Chelon auratus*, golden mullet), *Syngnathus caspius* (Caspian pipefish) and the clupeid *Clupeonella cultriventris* (= *C. caspia*, common kilka) increased in numbers since 1989. The fishery will require extensive engineering and management innovations to recover.

Pollution continues to be a problem in this heavily populated, industrial and farming region. Heavy rains in October 1995 swept industrial wastes including heavy metals such as lead and zinc, agricultural waste and domestic sewage into the talab. A fish kill resulted as evidenced by the talab being covered with floating dead fish. The kill was attributed to the heavy metals and to oxygen depletion (http://netiran.com:80/news/IRNA/html/941029IRGG01.html). A summary of pollution problems by heavy metals, pesticides and other chemicals is given below.

Higgins (1973) found that DDT levels in *Cyprinus carpio* and *Rutilus frisii* (= *R. kutum*) taken near Anzali were not hazardous to humans (0.2-1.8 p.p.m.), less than the limit for edible fishes set by the U.S. Food and Drug Administration at 5 p.p.m. Certain heavy metals, lead and silver, were potentially harmful to the fishes also. Nadim (1977) found the highest mercury levels in Caspian Sea fish, presumably from close to the Anzali Wetland, were 0.51 and 0.36 mg/kg in *Rutilus frisii* (= *R. kutum*) and *Esox lucius* (northern pike) respectively with the lowest in *Liza aurata* (= *Chelon auratus*, golden mullet) at 0.07 mg/kg. As the acceptable limit was 0.5 mg/kg, mercury contamination in fish was not considered a problem. The lowest zinc concentration was in *H. molitrix*, the highest lead concentration was in *C. carpio* and the highest cobalt concentration in *C. auratus* but concentrations were less than those set by the World Health Organization as significant. Södergren *et al*. (1978) reported on pollution with organochlorines in *Esox lucius* from the talab and found this predatory fish to have accumulated the DDT metabolite *p,p′*-DDE, suggesting that this occurred over considerable time and was not

a recent event. DDT did not appear to be incorporated in the pelagic food chain, although it has been used for agriculture and vector control problems. Most DDT probably attaches to clay and soil particles and settles out on the talab bottom. Pourang (1995, 1996), Amini Ranjbar (1998), Caspian Environment Programme (2001a), Sartaj *et al*. (2005) and Mansouri *et al*. (2013) described heavy metal concentrations (cadmium, chromium, copper, lead, manganese, nickel and zinc) in fish, surficial sediments and various macroinvertebrates of the Anzali Wetland. Levels in *Carassius auratus* and *Esox lucius* (northern pike) were below levels dangerous for human consumption. *Carassius auratus*, *Cyprinus carpio*, *Esox lucius* and *Hypophthalmichthys molitrix* in the Anzali Talab had zinc (5.39-27.98, mean 17.28 p.p.m.), cadmium (0-0.08, mean 0.0251 p.p.m.), cobalt (0-1.67, mean 0.6935 p.p.m.), lead (0.11-2.95, mean 1.04 p.p.m.) and mercury (0.113-0.63, mean 0.3 p.p.m.) in their muscle tissues (*Annual Report, 1995-1996, Iranian Fisheries Research and Training Organization, Tehran*, pp. 46-47, 1997). Mortazavi *et al*. (2012) documented the presence of phenolic endocrine disrupting chemicals in the talab, contaminating this habitat and potentially affecting fishes with cancerous tumors, birth defects and other developmental disorders such as feminising males or masculinising females. Mansouri *et al*. (2013, 2013) assessed the risk to humans of the contaminants cadmium, chromium and lead in Anzali Wetland fishes. The lead concentration in *Cyprinus carpio* was higher than the World Health Organization standard but levels for all the metals in *Abramis brama*, *Alburnus chalcoides* and *Carassius carassius* (probably *C. auratus*) were not. Panahandeh *et al*. (2014) measured heavy metal (cadmium, chromium, copper, lead, zinc) levels in Anzali water, sediment and in *Abramis brama*, *Carassius carassius* (probably *C. auratus*) and *Cyprinus carpio*. The exotic *Carassius* species had the best condition factor. Zinc had the maximum level in water and sediments followed by copper, lead, chromium and cadmium and this was mirrored in fish muscle. Copper and zinc were the most bio-accumulated and bio-magnified metals. Kadkhodaei *et al*. (2015) studied the levels of the organochlorine pesticides heptachlor, heptachlor epoxide and aldrin in sediments, macrobenthos and *Carassius carassius* (probably *C. auratus*) in the western lagoon of the wetland. Heptachlor epoxide had the highest level with a mean of 6.01 p.p.b. in fish, for example, and levels of all pesticides in sediments were higher than acceptable standards, but not in fish. Astani *et al*. (2016) investigated methyl mercury and total mercury concentrations in muscle tissue of *Carassius auratus*, *Cyprinus carpio* and *Rutilus frisii* (= *R. kutum*) from the Anzali Wetland, and the thermodynamic parameters of methyl mercury extraction from *R. kutum*. Kouhi Dehkordi *et al*. (2016) examined the effect of polluted water from the Abkenar and Siahkeshim parts of the Anzali Wetland on fry histopathology, finding lumen expansion and blood congestion in primary gill lamellae and focal necrosis in liver tissues after eight days of exposure. Mirzajani *et al*. (2016) examined *Alburnus chalcoides* and *Rutilus frisii* (= *R. kutum*) from the Anzali region for metal bioaccumulation (cadmium, chromium, cobalt, copper, iron, manganese, nickel, zinc) and found intakes were below legislated limits. Panahandi and Morovati (2018) examined the risk of heavy metals (cadmium, chromium, copper and zinc,) to the life of fish in wetland ecosystem and found the highest concentration was zinc (1.77 mg/l) in the central part of the wetland, the lowest concentration was chromium (0.027 mg/l) in the western part of the wetland, the highest concentration was zinc in *Esox lucius* (northern pike) muscle (26.34 µg/g), and the lowest concentration was cadmium (0.1µg/g) for *Alburnus chalcoides*. The risk assessment results indicated that cadmium and zinc in wetland water are at a high potential of risk for Anzali fish. Seifzadeh *et al*. (2018) measured anthracene, fluorene and phenanthrene hydrocarbons in fish from the Anzali Wetland. Anthracene was observed in *Cyprinus carpio* from the central station, *Rutilus kutum* from the west and east

stations and *Carassius auratus* from the central and west stations. *Cyprinus carpio* of the east station in terms of contamination with fluorene and *Cyprinus carpio* of the east and west stations were not suitable for human consumption. *Carassius auratus* of the west and east stations, *Rutilus kutum* of the central stations, and *Cyprinus carpio* of the central and east stations in terms of phenanthrene were also found unsuitable for human consumption. Mohammadi Galangash (2021) documented the threat posed by heavy metals to the biota of the wetland.

Daghigh Roohi (2016) surveyed parasites in Anzali Talab fish, finding 30 species and the first record of *Dactylogyrus inexpectatus* in *Carassius auratus gibelio* (actually first recorded in Daghigh Roohi *et al*. (2014)). The composition of parasite species has changed over time, the prevalence, intensity and abundance of parasites having increased. This may be due to changing environmental conditions such as increasing discharge of effluents and eutrophication of the wetland. Rezaitabar *et al*. (2017) examined levels of microsytin-LR, a toxin produced by the cyanobacterium *Anabaena* in Anzali Talab fishes. Consumption of fish, such as *Hypophthalmichthys molitrix*, by humans seemed unsafe.

Mercury concentrations in fish and fishermen's hair were studied from the Caspian shore by Zolfaghari *et al*. (2008). The mean hair mercury concentration was below the World Health Organization threshold level and there was a weak correlation between number of fish meals per month and mercury levels. Levels in *Vimba vimba* (= *V. persa*), *Rutilus rutilus* (= *R. lacustris*), *R. frisii* (= *R. kutum*), *Liza* (= *Chelon*) spp., *Carassius auratus* and *Esox lucius* (northern pike) exceeded U.S. Environmental Protection Agency guidelines. Amarloo *et al*. (2015) determined that allowable consumption rates for *Cyprinus carpio* caught in the wetland, based on mercury muscle content, had limitations. The average mercury concentration was 208.81 μg/kg compared to 334.47 μg/kg for the fish predator *Esox lucius* (northern pike).

Amini Rad (2001) assessed the socio-economic importance of fisheries in Bandar-e Anzali. Fishes are very popular food items there with an average consumption of 11.3 kg, 70% more than in the rest of Iran. White fish (sefid mahi, *Rutilus kutum*) was 1.5 times more expensive than mullets (Mugilidae), 2.6 more than other species and almost 28 times kilka. Yektaye Gorabi *et al*. (2015) investigated consumption of fish in Rasht, Gilan finding weekly had the highest frequency (32.75%) and monthly the lowest, and winter having the highest frequency (46.48%) and summer the lowest (13.07%). Priority was given to *Oncorhynchus mykiss* (rainbow trout), grass carp, silver carp and common carp, respectively. Caspian Sea fish were preferred over fish from southern waters (Persian Gulf). Fried fish at 91.75% was the most consumed form.

Gorgan (= Asterabad or Astrabad) Bay (36°40'N, 53°50'E) is 56 km long by 16 km wide and is brackish (8.7-10.0‰) because of input from rivers although Bayrami *et al*. (2003) gave 16‰. The bay encompasses about 400-450 sq km. A general description was given by Zanusi (1995) who considered it to be the second richest resource for caviar in the Caspian Sea after the Volga River. Lalouie (1993) surveyed the hydrobiology of the bay and found an average pH of 8.3, similar to the sea proper as were alkalinity and total hardness. Water temperatures ranged from 5°C to 30°C annually. Pollution from urban and industrial sewage and pesticides was present. The Caspian Environmental Programme (2001c) gave an average surface water temperature of 19.1ºC, oxygen from 2.4 to 11.1 mg/l, pH 8.0-8.5 and total dissolved solids 11.23 mg/l in February to 15,052 mg/l in March. The bay's ecology changed because of a rise in sea level which resulted in storm surges over the sand bar between it and the Caspian Sea. The construction of the Voshmgir Dam on the Gorgan River in 1970 also had an effect, reducing the amount of fresh water to the river mouth which provided spawning areas for *Cyprinus carpio*

and *Rutilus rutilus* (= *R. lacustris*). Mohammadkhani (2013) gave details of the ecology of the bay based on 11 stations in 2009. The biomass and frequency of phytoplankton, zooplankton and benthos were recorded along with hydrochemical parameters. Khoshravan *et al*. (2019) compared satellite images between 1977 and 2017 which showed that from 1995 to 2017, when the Caspian Sea level was reduced by 140 cm, about 20% of the Gorgan Bay was completely dried up and in 1977, compared to 1930 by a three-meter reduction in the sea level, about 40% of the bay area was completely dried. Gorgan Bay is now reduced to 360 sq km, while it was about 450 sq km, before the drought conditions. They also noted sea water level increments in 1978-1995 and 1998-2011. These fluctuations naturally affect the fish fauna. Ghorbanzadeh Zafarani *et al*. (2020) examined the macrobenthos and sedimentation characteristics of the bay and found the condition of the shallow western part was better than the deep eastern part. This was attributed to the hydrodynamic conditions and to the adverse conditions for different benthic species due to the proximity to rivers. Norouzi *et al*. (2021) studied fish dynamics in the bay using stable isotopes of carbon (13δC) and nitrogen (13δN) to assess diet and trophic status at five stations. Results indicated an imbalance in ecosystem conditions that altered the diet of organisms and reduced the efficiency of the food web. The main factors of pressure on the ecosystem were the closure of the main channels of the bay to the sea, the entry of various pollutants and the weak physiography of the bay.

Afraei Bandpei *et al*. (2018) described the species diversity in Gorgan Bay based on 4,292 fish samples caught in 2014. A decrease in the coefficient of variation over two decades was noted, attributed to the decrease in water level. Cyprinoidei at a frequency of 36.94% were second after Atherinidae at 48.9% (*A. caspia*, Caspian silverside). Cyprinoid species were *Carassius auratus*, *Cyprinus carpio*, *Leuciscus aspius*, *Rutilus frisii* (= *R. kutum*), *Rutilus rutilus* (= *R. lacustris*) and *Vimba vimba* (= *V. persa*).

The bay once had a valuable *Rutilus rutilus* (= *R. lacustris*) fishery with an annual catch of 4,000 t per year about 20-30 years ago but this disappeared (Petr, 1987). The bay is now dominated by Mugilidae (CEP, 1998). The catch in the Voshmgir Dam was 60 t in 1986 although it may improve with stocking programmes.

Gorgan Bay is believed to be an important nursery ground for *Liza aurata* (= *Chelon auratus*, golden mullet), a major food fish, although an exotic. Cage and pen culture operations in the bay may result in escapes of exotics that could affect native cyprinoid species. On three separate occasions, cages capsized in storms releasing millions of *Oncorhynchus mykiss* (rainbow trout) fingerlings (www.ramsar.org/ram_rpt_37e/htm, downloaded 4 May 2001). The effects of sturgeon pen culture on water quality in the bay were detailed by Farhangi *et al*. (2018). Sharbaty (2019) recommended changing the spacing of cages as lowering water levels reduced clearance of pollutants.

Cage culture along the whole Iranian Caspian shore is likely to affect native fishes. Afraei Bandpei *et al*. (2016) sampled eight transects at a depth of 5-100 m from Astara to Torkeman in 2008-2009 for macrobenthos and recommended cage culture at 20 m depths. Bagheri *et al*. (2016) found impacts on zooplankton abundance off Jafrud, Gilan at a rainbow trout cage culture site. Karimian *et al*. (2018) examined the impact of rainbow trout cage culture at Abbas Abad on the open Mazandaran coast, and found minor impacts on water quality factors and nutrient concentrations due to water movements and currents, and no remarkable effects on zooplankton structure in the vicinity of the fish cages, such that more zooplankton changes were associated with seasonal fluctutions. Dad *et al*. (2019), however, found some changes in macrobenthos near cages at Kelarabad, also on the open Mazandaran coast. Yazdani *et al*. (2019)

assessed the environmental efficiency of rainbow trout cage culture at Abbasabad, Babolsar, Juybar, Nowshahr and Tonekabon in Mazandaran. The average environmental efficiency of farms was 0. 599, indicating a high potential for reducing pollutant emissions and improving environmental efficiency. Based on the study findings, the weak technical knowledge of farmers, especially in choosing the right time for the start and end of production cycles, and feeding mismanagement will lead to an increase in the amount of pollutants released into the aquatic environment. Thus, it was suggested that successful farms be encouraged by incentive policies to transfer their experience to other farms in order to improve the environmental efficiency of the cage culture system. This could be done through training courses using well-trained instructors and successful farmers. Farabi *et al*. (2020) showed that the south-central area of the Caspian Sea in Mazandaran Province was the best area for cage culture. Floating cages at less than 20 m in depth accommodated fish tolerant of 26°C, such as cyprinoids, otherwise cages must be immersed deeper than 20 m.

The area of the Miankaleh Peninsula, Gorgan Bay and the nearby freshwater Lapoo-Zaghmarz Ab-bandans is designated as a Ramsar Site (World Conservation Monitoring Centre, 1990). The Miankaleh Wildlife Refuge encompasses 81,180 ha and is part of the Miankaleh Protected Region (97,200 ha). Jones (www.ramsar.org/lib_dir_2_3.htm, downloaded 14 April 2000) gave 68,800 ha for the Wildlife Refuge. The Miankaleh Wetland may encompass 40,000 ha, not the larger figures as originally designated (Khan *et al*., 1992). The bay has a sand and mud bottom and is oligotrophic. There are extensive marshes along the southern and eastern shores which flood in fall and winter. These marshes are eutrophic from agricultural runoff and stream and irrigation channel inputs. The bay vegetation comprises principally glasswort (*Salicornia*), sedges (*Carex*) and rushes (*Juncus*) with some small reedbeds of *Phragmites communis*. The ab-bandans have extensive reedbeds of *Phragmites communis* with stands of reed mace (*Typha*) and abundant submerged vegetation. Several factors will affect the ichthyofauna including irrigation requirements limiting freshwater flow into the bay and ab-bandans, a fish processing plant at Ashuradeh with associated wastes, a new road along the peninsula which facilitates access and potentially increased pollution and poaching, reed cutting, heavy livestock grazing, agricultural wastes, aquaculture ponds using exotics, fishing by local people, and a proposed nuclear power plant. The whole area is an important nursery and breeding ground for fishes. The ab-bandans are not protected although they are within the Ramsar Site. The two shallow ab-bandans occupy 950 ha at 36°50'N, 53°17'E northwest of Behshahr. They are fed by irrigation ditches and drain east into Gorgan Bay.

Saghali *et al*. (2012, 2014) found increasing levels of heavy metals in water, sediment, fish and benthos in Gorgan Bay. Ghorbanzadeh Zaferani *et al*. (2016) documented the distribution pattern of heavy metals in surficial sediments and concluded the Bay was at low risk although aluminium and nickel were higher than guideline levels in spring and arsenic in summer at some stations in the eastern part of the Bay. Mansouri (2016) also documented pollution in the bay and the risk of eutrophication. Alipour and Banagar (2018) studied heavy metals (cadmium, chromium, iron and lead) in muscles of fish from Gorgan Bay, including *Cyprinus carpio*, and found that consumption by humans did not represent an appreciable hazard risk. Bagheri *et al*. (2020) described the microplastics distribution, abundance and composition in sediment, fishes and benthic organisms in Gorgan Bay. *Rutilus caspicus* (= *R. lacustris*) was found to have microplastics although at much lower levels than the gobiid *Neogobius melanostomus* and the mollusc *Cerastoderma lamarcki*, for example. Maleki *et al*. (2020) used

the Palmer Algal Index for 23 stations in the bay and found all parts at all seasons to be highly polluted and at a critical level.

Mazandaran, Gorgan Bay and Miankaleh Peninsula
(CC0, NASA).

Mazandaran, Gorgan Bay
(Gulf of Gorgan 20160619 25, cropped, CC BY 4.0, Mehrnews, Aboutaleb Nadri).

Sharbaty (2016a, 2018) investigated the fate of Gorgan Bay as a semi-enclosed area when Caspian Sea levels decline as expected. The bay would become a disclimax (a relatively stable ecological community which often includes alien species displacing the climax because of disturbance, especially by humans) without riverine input, or a eutrophic wetland with river input. Sharbaty (2015, 2016b) modelled water renewal time in Gorgan Bay for determining the best areas to develop aquaculture and the appropriate distance between pen culture sites to allow for pollutant dilution.

Ghorbani *et al*. (2013) described the environment and the fish fauna of the small Kaboodval Stream east of Gorgan in Golestan Province. They found four fish species including *Capoeta capoeta* (= *C. razii*) and *Alburnoides eichwaldii* (*sic*, presumably *A. tabarestanensis*) and noted that many environmental factors were involved in the fish distribution and separating the effects of these was difficult.

Gorgan Bay is a type locality for *Alburnus striatus* (= *A. hohenackeri*).

There are a number of lakes, marshes or wetlands along the Iranian shore of the Caspian Sea in addition to the major ones of the Anzali Talab and Gorgan Bay, and some are described below.

The Astara or Estil Lagoon is a Ramsar Site at the western end of the Caspian coast of Iran is separated from the Caspian Sea by a sand bar, and is flooded across this bar during winter storms. The lagoon encompasses about 950 ha and is fed by a river during August to March, reducing its salinity to about 7 p.p.m. There is a rich growth of aquatic plants and the area has potential for fishing and aquaculture (Petr, 1987). The Astara River contains organochloride pesticide residues with the most pollution seen in July and the least in September (Hosseinibehbahani *et al*., 2012). Lavandavil Marsh at 38°20'N, 48°50'E is found about 10 km south of Astara and lies within a Protected Area of 949 ha. It is a small swampy woodland and freshwater marsh with extensive stands of *Juncus*. Abbasabad Dam at 38°23'N, 48°50'E south of Astara is a 45 ha water storage reservoir.

Gilan, Estil Lagoon
(CC BY-SA 3.0, cropped, lightened, Samaksasanian).

Nur, Neor or Neur Gol at 38°00'N, 48°33'E in the northwest Alborz Mountains is a 220 ha freshwater lake with a mean depth of 5.3 m lying at 2,300 m about 50 km south of Astara. It lies within the Lisar Protected Area which includes the whole watershed of the Lisar River. The lake drains north to an Aras River tributary but freezes over for about 4-6 months each year. The submergent vegetation is rich. *Oncorhynchus mykiss* (rainbow trout) were introduced to the lake in the early 1970s in an attempt to start a sport fishery as the lake was fishless. Khodaparast Sharifi *et al*. (2016) noted that *Carassius gibelio* was introduced in 2006 and water quality changed, the lake becoming hyper-eutrophic, attributed in part to the cyprinid introduction. Khodaparast *et al*. (2018, 2018) and Fallahi Kapourchali *et al*. (2019) noted introduction of *C. gibelio* was in 2003 and this fish affected the lake ecosystem and competed with the rainbow trout for food, leading to the loss of the fishery for the trout. The stock of goldfish was 12.91 t in 2014. There is also a number of permanent and seasonal lakes along the Sabalan Mountain range which lies partly in this basin and partly in the Lake Urmia basin and these are known to have fishes (www.netiran.com, downloaded 17 June 2004).

Gilan, Neor Lake


The Lapu Lake or Lapu'i Marsh, about 20 km northeast of Sari in Mazandaran, is an example of a smaller water body along the Caspian shore, covering about 100 ha with a maximum depth of about 2.5 m, perhaps 3.5 m in winter (Petr, 1987). There is a rich assortment of aquatic plants. In 1985, 90,000 fingerlings of common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypophthalmichthys molitrix*) were stocked and 120,000 fingerlings were added in 1986. A good harvest was reported in 1986. There is a wide variety of reservoirs on the Caspian shore, varying in size from about 10 to 400 ha. Some completely dry out in summer when water demands are high but others are stocked with common carp, silver carp and, to a lesser degree, grass carp. There are also populations of native fishes such as kopur (*Cyprinus carpio*) and ordak mahi or northern pike (*Esox lucius*) but not in commercial quantities.

Mazandaran, Lapu Lake
(view of the power plant from Lepo (in Farsi), CC BY 3.0, zs.shervin).

The Amirkelayeh Lake, Lagoon or Wetland is located between the cities of Lahijan, Langarud and Kiashahr at 37°17'N, 50°12'E. It is an example of a larger, freshwater lagoon as it encompasses 1,230 ha, being 4.5 km long and up to 1.7 km wide. The lake is in the Amirkelayeh Wildlife Refuge and is a Ramsar Site (World Conservation Monitoring Centre, 1990). Average depth is only 1.6 m although some areas reach 4 m (Scott (1995) stated 3-4 m on average but up to 6 m). The lake is fed by springs and precipitation. Golmohammadi and Shariati (2017) examined its trophic status over one year with the main threats being agricultural runoff and water abstraction for agriculture. It was mesotrophic in autumn and winter, acutely mesotrophic in spring from agricultural runoff and eutrophic in summer from runoff and high temperatures. Amini *et al*. (2020) also examined the trophic status and found sewage drainage and runoff from surrounding areas to be negative factors requiring management. The wetland lies above the 1980s rise in water level of the Caspian Sea (Khan *et al*., 1992) and also the 1990s rise. It may flood into marshes or the Caspian Sea via a small stream into a channel of the Sefid River. Vegetation is *Phragmites communis* and *Typha* with abundant submerged and floating plants such as *Ceratophyllum*, *Lemna*, *Hydrilla*, *Myriophyllum*, *Nelumbium* and *Potamogeton*. The fishes comprise *Esox lucius* (northern pike), *Sander lucioperca* (pike-perch), *Carassius* sp. (listed as crucian carp, probably *C. auratus*), *Blicca bjoerkna*, *Syngnathus caspius* (Caspian pipefish), *Pungitius platygaster* (southern ninespine stickleback), *Silurus glanis* (European catfish), *Rutilus rutilus* (= *R. lacustris*), *Cyprinus carpio,* and *Tinca tinca. Ctenopharyngodon idella* has been introduced (Nejatsanatee, 1994). Otters (*Lutra lutra*) are predators on fish in this wetland (Hadipour *et al*., 2011).

The Fereydun Kenar Marshes at 36°35'N, 52°31'E lie 13 km southwest of Babol Sar in Mazandaran and occupy 1,000 ha. These marshes are artificial, being a *damgah* or shallow impoundment for duck hunting and water storage for rice fields. They were one of the best protected wetlands along the Caspian shore as the local duck hunters' aggressively restricted

access (Khan *et al*., 1992; Vuosalo-Tavakoli *et al*., 2018). There are fringing reed beds of *Phragmites australis* and *Typha* with abundant floating and submerged vegetation. Sadeghi Zadegan (2018b) gave an overview of this Ramsar Site. There are four damgahs, Feryedun Kenar, Ezbaran and the East and West Sorkh ruds or rivers. There is a small wildlife refuge of 48 ha in the northeastern part of the area (Fereydun Kenar Wildlife Refuge). Small creeks, canals and reservoirs support a fish fauna but most reservoirs are drained over the course of the year so the ichthyofauna is relatively poor with about 10 species including *Abramis brama*, *Alburnus chalcoides*, *A. hohenackeri*, *Cyprinus carpio*, *Luciobarbus capito*, *Rutilus kutum*, *R. lacustris* and *Vimba persa*. The Sorkh River pesticide levels were detailed by Mohammad Shafiee (2001).


Mazandaran, Fereydun Kenar Marshes, before (a) and after (b) water birds migration, (CC BY 4.0, Jamal F. Hosseini).

Seyed Mohalli, Zarin Kola (both at 36°44'N, 53°00'E) and Larim Sahra (36°45'N, 53°03'E) are ab-bandans and associated marshy areas found north of Sari and east of the Tajan River mouth. The first two occupy 600 ha and the last one 1,000 ha. Aquatic vegetation is rich, both submerged and floating, and there are extensive stands of *Typha* and *Phragmites*. Construction of a large dam on the Tajan will result in an associated network of irrigation canals which may cause ab-bandans to be neglected. The ab-bandans, although artificial, have more of the character of a natural marsh than irrigation channels. Much of this area of the coastal plain has been converted to agriculture which destroys natural wetlands so ab-bandans take on a disproportionate importance as a refuge for wildlife including fishes.

The Gomishan Marshes or Wetland at 37°15'N, 53°55'E extend along the eastern shore of the Caspian Sea from Gomishan north and northwest to the Turkmenistan border. There are about 4,850 ha of brackish lagoons and marshes, their brackish nature occasioned by the rise in Caspian Sea level. There is agriculture, livestock grazing and waterfowl hunting. Riazi (2001) described the ecosystem structure. Cyprinoids recorded were *Cyprinus carpio*, *Rutilus frisii kutum* (= *R. kutum*) and *Rutilus rutilus caspicus* (= *R. lacustris*). The area is probably an important breeding ground for the commercially important *Liza aurata* (= *Chelon auratus*, golden mullet) (www.ramsar.org/ram_rpt_37e.htm, downloaded 4 May 2001), for *Rutilus rutilus* (= *R. lacustris*) and for *Sander lucioperca* (pike-perch), and the latter two are open to hydrocarbon pollution (Ghasempouri and Esmaili Sari, 2002). Khodashenas *et al*. (2016) studied effluent from shrimp farms north of Gomishan in Golestan Province and, while finding increased conductivity and total dissolved solids, concluded there was no serious threat to the Gomishan Wetland.

Golestan, Gomishan Wetland (CC BY-SA 4.0, *Islamic Republic News Agency*).

Various dams have been built or are under construction in the Caspian Sea basin including the Gourchye Embankment Dam 15 km southeast of Ardabil with a capacity of 20 million cu m, the Yamchi Dam 20 km southwest of Ardabil and the Gaybeglou Dam 40 km south of Meshgin Shahr in East Azarbayjan Province, the Maku Dam with a 150 million cu m capacity in West Azarbayjan and the Agh Chay or Ziaeddin Dam near Khvoy (http://netiran.com/news/IRNA/html/950914IRGG06.html; http://netiran.com/news/IRNA/html/950914IRGG10.html; http://netiran.com/news/IranNews/html/96102201INEC.html). The Polrud (= Pol-e Rud) Dam in eastern Gilan has a capacity of 30 million cu m and its environmental impact has been studied by Moradi *et al*. (2010). The Neka Power Plant in the eastern Caspian basin entrains a large amount of debris and algae that prevent effective physical systems of fish protection from entrainment. An electrical fish protection system is used instead. Laluie (1996) and Maghsudi *et al*. (2015) gave details on the effects of the power plant on the Neka River and significant heavy metal pollution in the sediments from coal mining and urban and wood industry sewage.


Mazandaran, Neka River (CC BY 3.0, apsez63).

Inflatable rubber dams are now being constructed in the lower reaches of rivers, e.g., the Babol, to block the rise in Caspian Sea level such that agricultural water intakes will not be contaminated with saline water. The effects of these dams on fish migrations and biology is unknown (www.satujo.com/english/barrage/dams4.htm, downloaded 20 December 2002).

Qanats and springs are not a feature of this basin as in so many other parts of Iran, except for the drier areas drained by the Qezel Owzan and other streams of the plateau and in the drier valleys of the east away from the rainfall of the Alborz-backed Caspian lowlands. One particular artificial habitat for fishes in the lowlands are the ab-bandans as described above. These shallow freshwater marshes are maintained as habitat and overwintering areas for waterfowl and for conserving water for rice fields (Beaumont and Neville, 1968). Some ab-bandans around the Anzali Talab were set aside as refuges for waterfowl and incidentally would protect some fish species threatened by the draining of marshes. Construction of irrigation dams will also lead to abandonment of ab-bandans. Ab-bandans and damgah (ponds made specifically for duck trapping) have declined in number but still encompassed 10,000 ha (Scott, 1995).

Extensive stocking of commercially important cyprinoid species takes place annually in the Caspian waters of Iran. These are detailed under the Species Accounts. Varedi and Fazli (2005) examined the rivers Goharbaran, Larim, Shirud, Tajan and Tonekabon of Mazandaran for the physico-chemical properties of estuarine water in 2000-2001. Only the Shirud and Tonekabon met U.S. Environmental Protection Agency standards for release of fingerlings, the other rivers failing because of water abstraction and improper land use development. The Shirud has been studied extensively for its fishes, covered in the **Species Accounts**. It is about 36 km long with a width at the estuary of 50-80 m and a depth of 1.5-2.5 m. The substrate is pebble mixed with gravel and sand, there is a high water flow, and water clarity is high (Nazari and Abdoli, 2010).

Jamali *et al*. (2012) evaluated two natural, 200 ha ponds in Mazandaran near Babol and Sari for aquaculture development. Most parameters were at an optimum and those that were not

could be controlled for successful fish farming. Pourgholam *et al*. (2013) found that Mazandaran warmwater fish ponds benefited from a mix of cow manure and chemical fertilisers, with higher levels of phytoplankton and zooplankton, and reduced costs as less chemical fertiliser was needed. Behmanesh *et al*. (2017) examined warmwater aquaculture in the northern Alborz Region of Gilan by means of questionnaire forms filled in by fish farmers. Private farms comprised 89.3%, cooperative farms 7.1% and governmental farms 3.7%. Polyculture comprised 92.6% of farms, monoculture 3.7% and integration 3.7%. Only 17.9% of fish farmers used an expert on their farm. Limitations listed included management problems, low oxygen demand in the ponds, miss water inlet (*sic*), high fish density, poor quality of fish feed, disease, pollution and transport conditions. Mortality factors were cloudiness, drought, high temperatures, glacial (*sic*), floods and storms.

Much of the Caspian coast was once forested, but it has been actively cleared and marshes reclaimed as rice paddy. Rice paddies are now being investigated for fish cultivation. About 300-500 kg of carp "seed" (= eggs or larvae) and a 10% increase in paddy production per hectare was recorded during the rice cultivation season. Extending this into the fall gave a production of 750,000 kg of fish and duck and in winter 5.5-8.0 t of *Oncorhynchus mykiss* (rainbow trout) (*Tehran Times*, 1 October 2000).

Gilan, south of Hashtpar, rice paddies, 5 June 1978, Brian W. Coad.

Mazandaran had the highest farm fish production in Iran at 28,000 tonnes (2006-2007) and was expected to reach 50,000 t by 2010 (www.mehrnews.ir, downloaded 8 February 2007).

A wide variety of parasites have been recorded from fishes in this basin and these are mostly dealt with in the Species Accounts. Bozorgnia (2007), for example, recorded parasites from *Carassius auratus*, *Cyprinus carpio*, *Luciobarbus capito* and *Rutilus kutum*. Pazooki *et al*. (2008) recorded seven monogenean species from 11 fish species in the Aras, Ghotor and Zangbar rivers of northwest Iran, namely *Dactylogyrus chramuli*, *D. extensus*, *D. kendalanicus*, *D. lenkorani*, *Diplozoon megan*, *Gyrodactylus varicorhini* and *Silurodiscoides siluri*. Sharifpour *et al*. (2014) studied parasite faunas on Chinese major carps from 31 fish farms in Golestan Province. In 2008, 56.25% of farms had infestations and in 2009 93.3%, and *Trichodina* sp., at

60%, was the most abundant parasite. Panahinia *et al*. (2020) recorded *Rhabdochona denudata*, *Rh. fortunatowi* and *Rh. hellichi* from *Alburnoides bipunctatus* (= *A. tabarestanensis*), *Capoeta capoeta* (= *C. razii*) and *Squalius cephalus* (= *S. turcicus*) in the Babol, Haraz, Tajan and Talar rivers.

Mostafavi *et al*. (2015, 2015) developed a multi-metric index for cyprinoid streams in the Caspian Sea basin, useful in the assessment of environmental degradation and therefore water resource management. For cyprinoid streams, the dominating human pressure was agricultural land use, followed by hydrological and morphological pressures. Multiple pressures dominated in the "cyprinid" zone compared to double or triple pressures in the salmonid zone. Mostafavi and Teimori (2018) analysed human pressures on Iranian Caspian Sea rivers finding most areas were impacted by land use pressure followed by water quality and most areas were threatened by multiple pressures. Pressures included acidification, agriculture, channelisation, downstream and upstream migration barriers, eutrophication, flood protection, flow velocity increase, hydropeaking, impoundment, introduction of fish, organic pollution, organic siltation, other pressures, pressure of exploitation, reservoir flushing, sedimentation, temperature pressure, toxicity, urbanisation and water abstraction. Mostafavi *et al*. (2019) developed a multi-metric index for coldwater streams dominated by native brown trout, noting that at impacted sites other species could be dominant including the cyprinoids *Alburnoides eichwaldii* (*sic*, presumably a mix of *A. samiii* and *A. tabarestanensis*), *Barbus lacerta* (= *B. cyri*), *Capoeta capoeta* (= *C. razii*) and *Squalius cephalus* (= *S. turcicus*). Mostafavi and Ghafarikhah (2021) recommended landscape assessment to protect biodiversity in the southern Caspian Sea basin.

Dasht-e Kavir

The Dasht-e Kavir or "Low Plains" occupies an immense area of north-central Iran, over 200,000 sq km in the rain shadow of the Alborz Mountains.

Dasht-e Kavir basin
(includes part of Bejestan in the east on other interpretations)
(IranCatchCen2, CC BY-SA 4.0, Mahdy Saffar).

Mahdavi and Anderson (1983) detailed the qanat water supply of the margins of this basin. Intermittent streams drain to several kavirs which are grouped together under this basin for convenience. The principal kavirs are the Damghan Kavir in the north, the Sabzevar Kavir in the north-east and the Kavir-e Bozorg (or Great Kavir) occupying much of the basin, being about 450 km in east-west extent and 250 km in north-south extent. The Kavir-e Bozorg receives waters exiting from other kavirs. The principal streams entering this basin drain the Alborz Mountains and their eastern extensions in the Khorasan provinces. The Alborz peaks exceed 4,000 m and even to the east the Kuh-e Binalud (36°30'N, 58°55'E) attains 3,416 m near Neyshabur (36°12'N, 58°50'E) while the lowest points are at an altitude of 650 m. The Damghan Kavir receives two major streams from the Alborz, the Damghan River and the Hasanabad River, and other streams dry up in early summer. Cheshmeh Ali, the source of the Damghan River, is unpolluted but lower reaches of the river receive agricultural and rural wastewaters and are polluted (Rezaie Tavabe *et al*., 2017). *Schizothorax pelzami* and *Schizothorax pelzami iranicus* (= *S. pelzami*) were described from the Damghan basin most probably. Cheshmeh Ali is the type locality of *Alburnoides damghani*. Pollution levels in six springs in the northern Damghan basin were described based on the macrobenthos fauna by Toosi *et al*. (2012).

The Hableh, Hable or Habla River originates northeast of Firuz Kuh (where it is known as the Firuz Kuh River) and flows southwest for 240 km, receiving several tributaries before terminating in the northwest Dasht-e Kavir. The Namrud (= Nam River or Qazqan Chay) joins the Firuz Kuh River near Firuz Kuh to form the Hableh River. The Nam River is the type locality for *Alburnoides coadi* (= *A. namaki*) and *Capoeta alborzensis* (= *C. aculeata*).

Tehran, Nam River, Hamid Reza Esmaeili.

Semnan, Hableh River north of Garmsar, Hamid Reza Esmaeili.

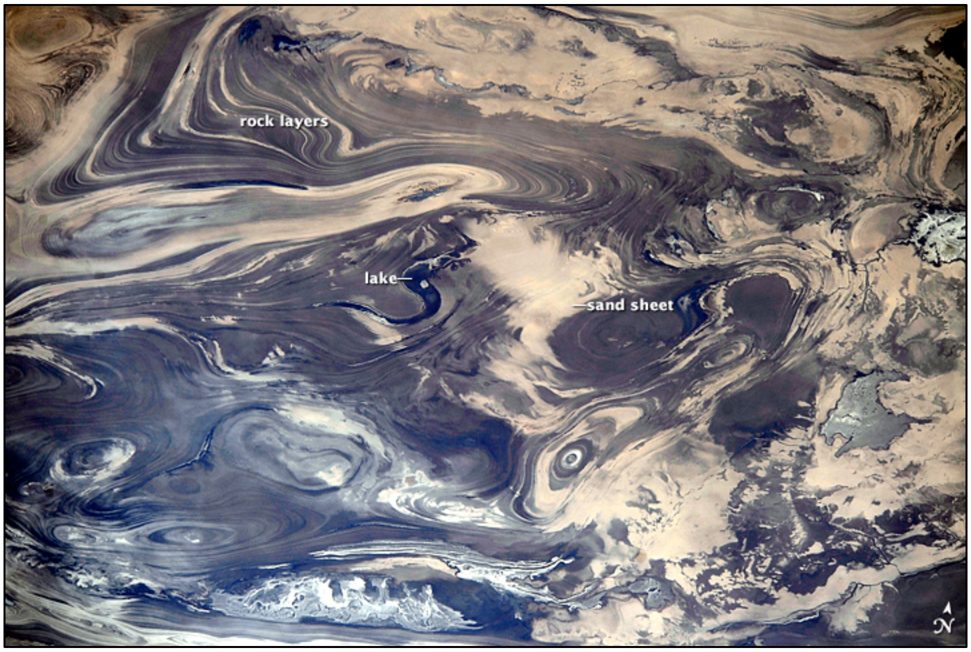
Sadeghi *et al*. (2013) examined 12 qanat stations around Shahrud in the northern part of this basin east of Damghan. Species recorded were *Alburnoides nicolausi*, *A. petrubanarescui*, *A. qanati*, *Capoeta aculeata*, *C. buhsei*, *C. capoeta*, *C. fusca*, *C. trutta*, *Carassius gibelio* and *Carassius* sp. The only valid species is presumably *C. fusca*, the others being misidentifications. The *Alburnoides* species could be *A. damghani*, *C. capoeta* could be *C. razii* and the *Carassius* species *C. auratus*.

Ebrahimian *et al*. (2014) examined fishes from the major water bodies in Semnan Province in the northern Dasht-e Kavir for parasitic worms. The fish species reported were *Alburnoides bipunctatus* (presumably *A. namaki*), *Alburnus charusini* (identity uncertain), *Capoeta capoeta gracilis* (presumably *C. razii*) and *Cyprinus carpio*. The parasites were *Dactylogyrus lenkorani*, *Dactylogyrus* sp., *Diplozoon megan*, *Gyrodactylus* sp., *Ligula intestinalis* and *Paradiplozoon* sp.

The Sabzevar Kavir has numerous small and temporary streams which feed it as well as two major streams, the Mureh River, 320 km long, and its tributary, the Kalshur or Kal-e Shur River, 240 km long. The Kal-e Shur drains the Kuh-e Binalud and flows west to meet the south flowing Mureh. These rivers drain areas rich in salt domes and samples taken show water to be saline and some streams are fishless. Qanats support fishes in this area although the fish only emerge at night in some cases. Ruttner-Kolisko (1964, 1966) and Ruttner and Ruttner-Kolisko (1972, 1973) studied the chemistry and limnology of natural springs and qanats in a mountain area separating this basin from the Bejestan basin. Several factors were found to affect the limnology. Climatic factors were temperature, precipitation and evaporation, edaphic factors were geology, salt content of soil and intensity of waterflow, and pollution by man and animals was a factor. There was a range in salinity from low (<15 mval/l) to high (>120 mval/l). Qanat discharges in this area were 20-50 l/sec. Springs were small and many were dammed to form small pools for livestock. Illegal groundwater pumping for irrigation has led to salinisation from intrusion of more saline water (Baghvand *et al*., 2010).

Razavi Khorasan, Kalshur River (CC BY-SA 4.0, M. M. Sad).

These large central basins of Iran were once thought to be desiccating lake basins. More recent studies have shown that although there may have been shallow lakes, e.g., saline Lake Damghan, and rivers carried more flow and were perhaps more closely linked than today, there was no extensive and continuous freshwater lake over the whole of central Iran that could have facilitated fish dispersal. While the hills received increased rainfall, the central deserts remained arid during Pleistocene pluvials and cold phases (Bobek, 1959; Scharlau, 1968; Krinsley, 1970).



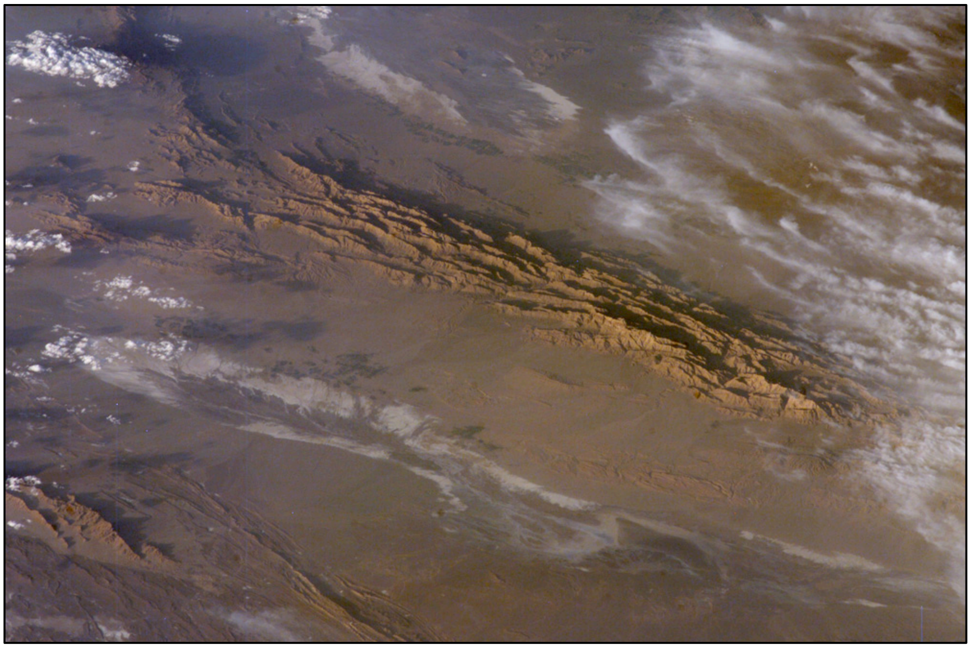
Dasht-e Kavir, false-colour composite image using infrared, green and red wavelengths (CC0, NASA).

Dasht-e Lut

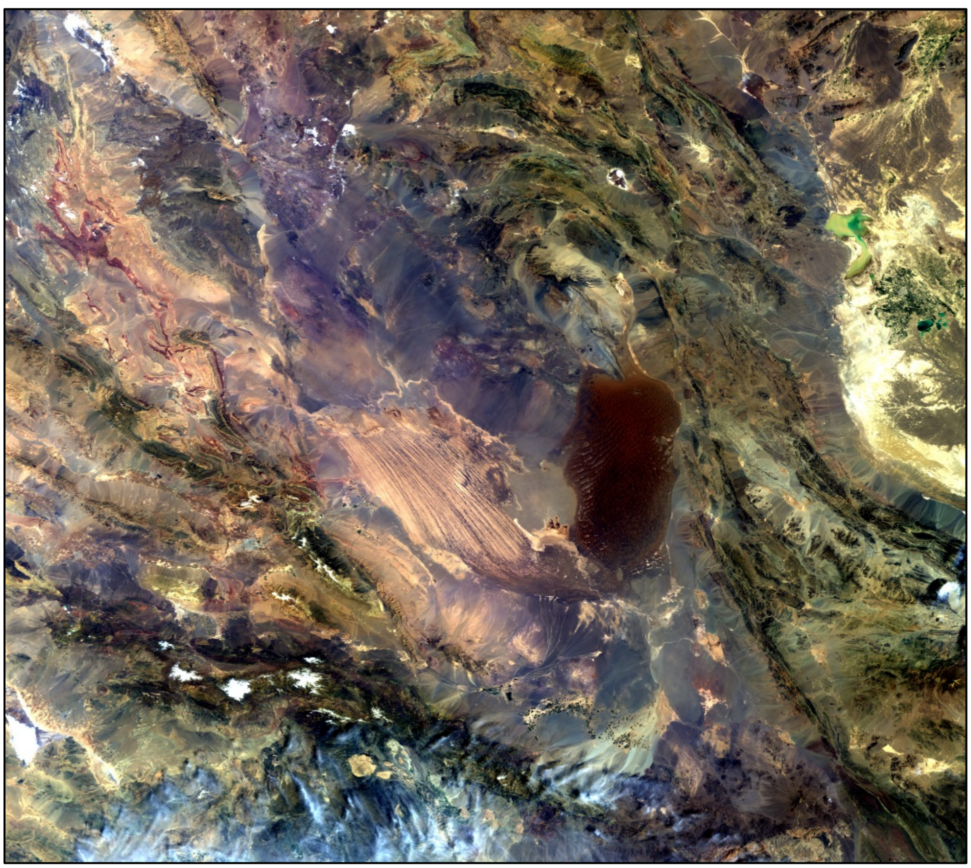
The Dasht-e Lut or “Emptiness Desert” of south-central Iran is ringed by mountains yet has the lowest point on the plateau at 205 m in the Namakzar-e Shahdad. The central portions of this basin are some of the most barren and inhospitable in Iran or indeed the world. Soil surface temperatures have reached 80.8°C, the hottest in the world (*Daily Mail*, 21 May 2021).

Dasht-e Lut basin
(IranCatchCen5, CC BY-SA 4.0, Mahdy Saffar).

Conrad and Conrad (1970) and Gabriel (1938) gave descriptions of this desert basin. Intermittent streams drain the mountain ranges around Kerman east to the namakzar or namaksar (= salt waste), north from mountains near Bam (29°06'N, 58°21'E) such as the Kuh-e Jebal Barez (28°30'N, 58°20'E) and Kuh-e Bazman (28°04'N, 60°01'E) which delimit the northern edge of the Hamun-e Jaz Murian basin, west from the slopes of the active volcano Kuh-e Taftan (28°36'N, 61°06'E) and south from the mountain ranges near Birjand (32°53'N, 58°13'E). High points include the Kuh-e Hazaran west of Bam and south of Kerman at 4,402 m. Such heights retain snow and have more abundant precipitation which feed streams at least in the mountains. Many minor and some apparently major streams marked on maps are completely dry. Much of the water is absorbed into the ground and tapped by qanats. The Shah River at Birjand is dry through most of the year (Fisher, 1968) and many streams are highly saline. Tabas (33°36'N, 56°54'E) at the northern end of this basin has numerous qanats (Krinsley, 1970).



Dasht-e Lut, western edge
(CC0, NASA).

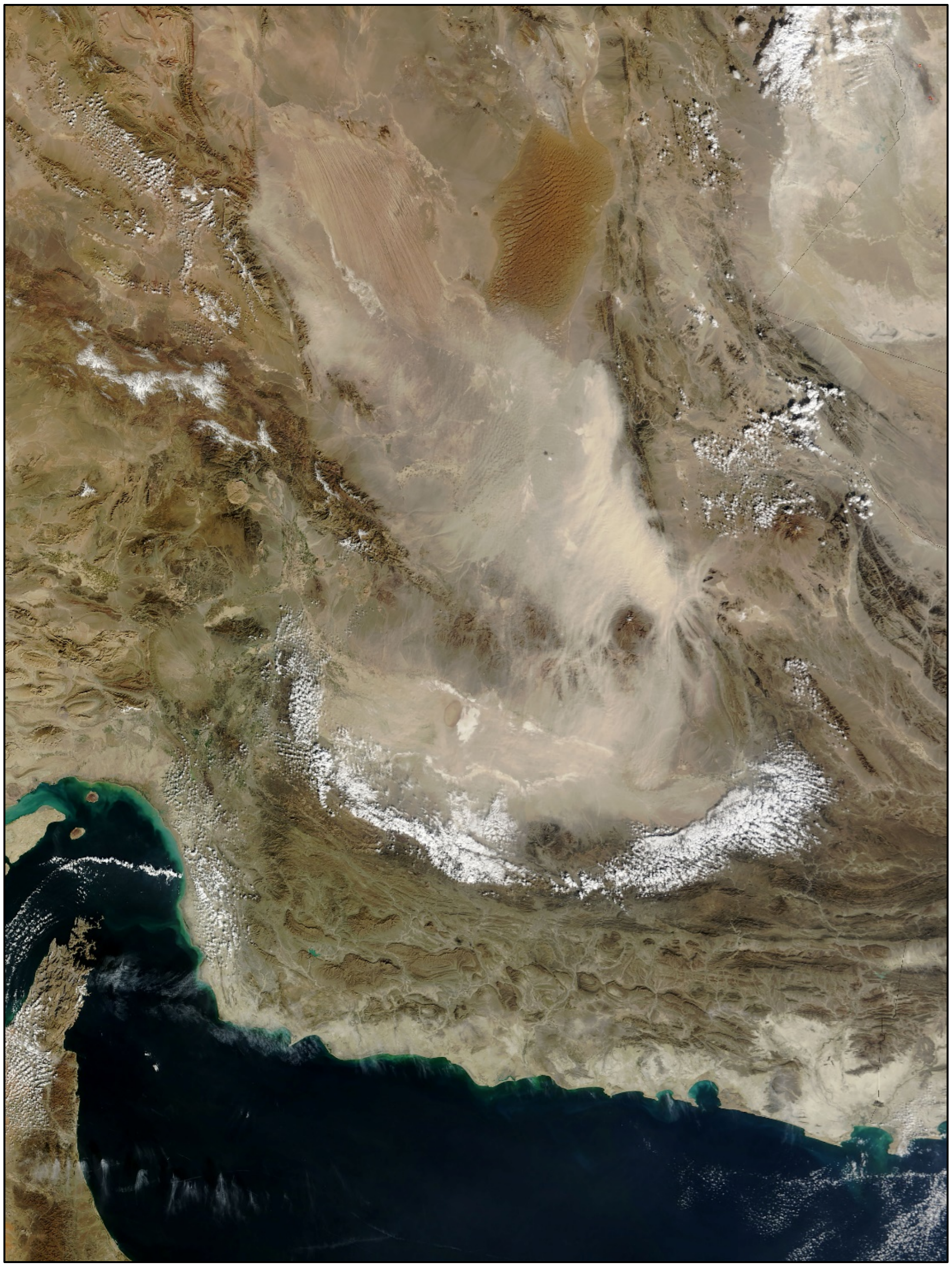


Dasht-e Lut, with wind-carved ridges at centre and green water body on Afghan border at upper right
(Dasht-e Lut salt desert Iran, CC BY-SA 3.0 IGO, European Space Agency).

The Shahdad River is presumably in this basin based on maps and supplies water to Kerman and some nearby villages. One sample station was polluted by wastes from an *Oncorhynchus mykiss* (rainbow trout) farm (Rezaei Tavabi *et al*., 2009). The Tahrud is an important stream which drains the Hazaran to a small sump in the south of the Dasht-e Lut basin and has a continuous flow which becomes subsurface well east of Bam (compare maps). Its maximum map extent approaches 250 km. In the mountains, the Tahrud is 1-8 m wide and up to 50 cm deep. Water temperature was a warm, 15°C on a cool December day. Seasonal lakes are often saline and fishless.

Kerman, seasonal lake north of Shahdad (CC BY-SA 4.0, lightened, ImanFakhri).

The Dasht-e Lut includes the largest sand dune field in Iran (ca. 10,000 sq km) which has developed through aeolian erosion. Sand dunes block roads and may well fill in or divert streams. Dust storms may also affect the shallow stream habitats of this basin, and other basins in Iran.


Dust storm in the Dasht-e Lut, 23 January 2010 (CC0, NASA).

Qanats in this basin can have water temperatures much higher than the few surface streams. One qanat near Bam had a temperature of 25°C in a snowstorm on 22 January 1977 (CMNFI 1979-0168), yet stream temperatures below 10°C are not uncommon.

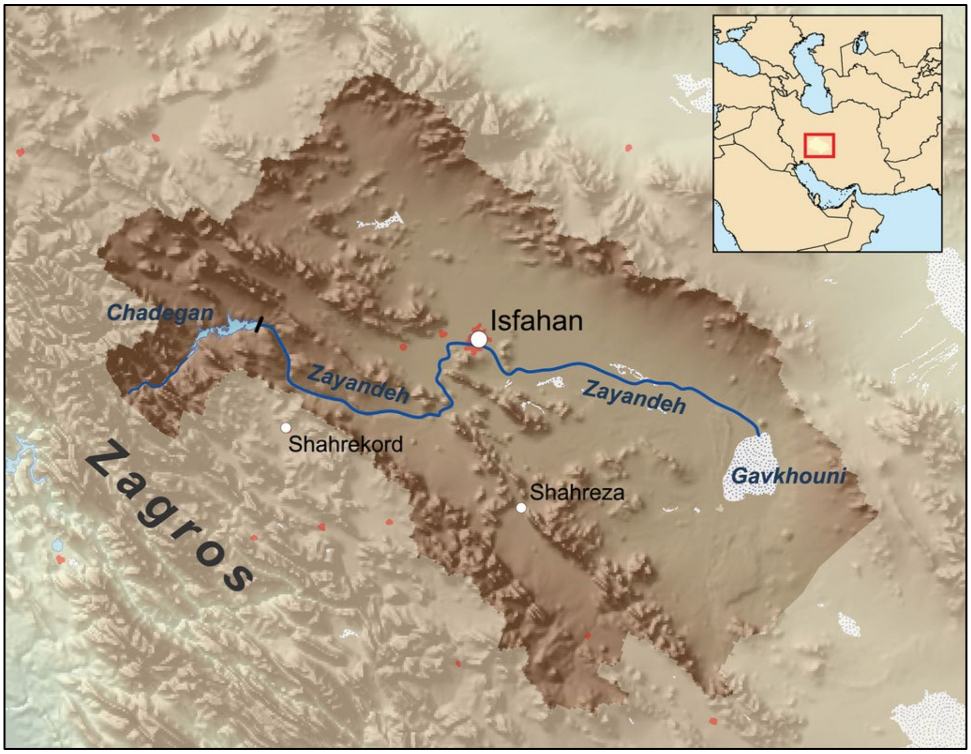
The southern Lut basin is a type locality of *Discognathus rossicus* var. *nudiventris* (= *Garra nudiventris*) and east of Kerman is the type locality for *Scaphiodon chebisiensis* (= *Capoeta saadii*).

## Esfahan

The Esfahan or Isfahan basin lies on the central plateau of Iran. The principal feature of this basin is the Zayandeh (= life-giver) River which rises in the Zagros Mountains east of Zard

Kuh at 4,548 m (32°22'N, 50°04'E) and flows east for 405 km with an average annual discharge of 1,053 mcm, according to the Encyclopædia Iranica (www.iranicaonline.org/, downloaded 10 July 2016). Flows from September to February are 20-30 m/second because of dry summer conditions and cold winter conditions locking up snow in the upper basin, and peaks are in April-May at 125-130 m/second (Molle *et al*., 2009). Murray-Rust *et al*. (2002), Salemi *et al*. (2005) and Mohajeri *et al*. (2016) gave analyses of integrated water resource management, development and water utilisation in this basin. Gohari *et al*. (2014) noted that snowfall decrease in winter months will lead to an 8-43% reduction in annual stream flow under climate change. Managing reservoirs for agriculture and other water uses in this system will inevitably affect fish populations. The type locality of *Alburnus maculatus* (= *A. doriae*) is probably a qanat near Esfahan, the Daran River lies in the Zayandeh River basin west of Esfahan and is the type locality of *Capoeta birunii* (= *C. coadi*), a canal (or qanat) near Esfahan is the type locality of *Capoeta gracilis*, and a stream in the southern Zayandeh River basin is the type locality for *Petroleuciscus esfahani* (= *Alburnus doriae*).

Esfahan basin
(IranCatchCen3, CC BY-SA 4.0, Mahdy Saffar).

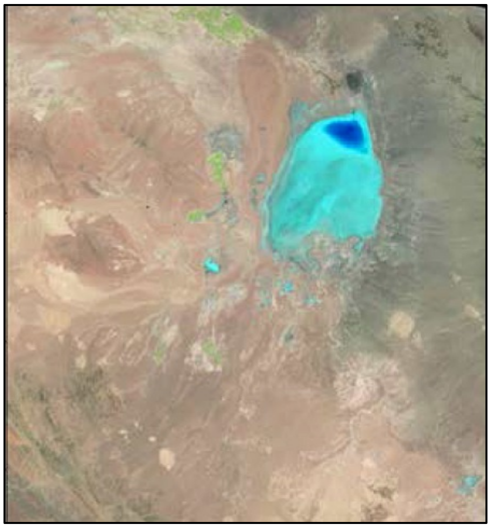


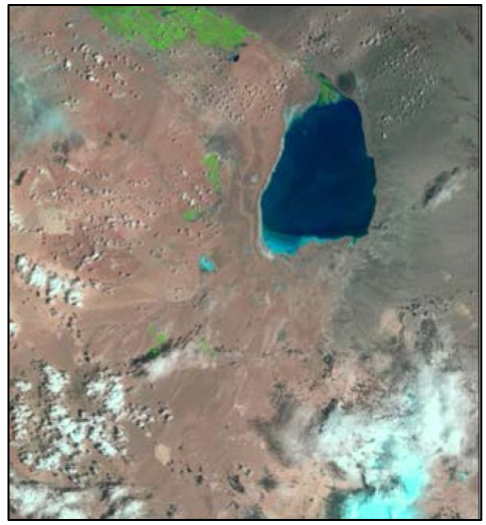

Zayandeh River basin
(Zayandeh River map, CC BY-SA 3.0, Kmusser).

The terminal basin, the Batlaq-e Gav Khuni at 32°20'N, 52°47'E, is a salt marsh with a salinity of 315‰ (Löffler, 1961). It lies at 1,470 m and has an average depth of 1 m. The Batlaq (= salt lake or marsh, gav khuni = cow shed because cattle are put out to pasture in the marshes) is fishless but the marshes have a freshwater character depending on the input from the Zayandeh River. The substrate is silt and mud. Much of the marsh has been converted for agriculture. Flooded areas may freeze over in winter. The salt lake is said not to dry out completely (Mehrabi, 2004) although flows were down to 10-100 l/s in the dry years 2000-2002 and the lake did dry out (Esteky, 2006). The salt marsh also dried up in the summer of 2014 (*Financial Tribune*, 15 November 2014). The Batlaq-e Gav Khuni and marshes on the lower Zayandeh are a Ramsar Site, the lake occupying 12,000 ha, permanent marsh 1,000 ha and temporary marsh 30,000 ha (World Conservation Monitoring Centre, 1990) or 47,000 ha (Mehrabi, 2004) (sources vary as does the size of the marsh seasonally and annually). Associated marshes at the river delta and along its banks are fresh to brackish. These marshes are fed by flooding and by irrigation canals but dry up in late spring or early summer. There is little natural marsh vegetation and flooding occurs over degraded steppe and cultivated land. Najari (2003) described the wetland in Farsi. The environmental water requirements of the wetland are summarised by Sarhadi and Soltani (2013) and Soltani *et al*. (2016). Abolhasani *et al*. (2018) assessed primary production in the wetlands and gave details of water chemistry characterising them as mesotrophic. Input of agricultural wastewater may lead to a eutrophic state.

Esfahan, Gav Khuni,
(Gavkhouni 20190422 13, CC BY 4.0, Hamidreza Nikoomaram).

Esfahan, Gav Khuni
(CC BY 4.0, cropped, sharpened, *Tasnim News Agency*, Morteza Salehi).





Esfahan, Gav Khuni Wetland
(light blue = shallow water area in May 1993, and dark blue = deep water area in May 2013)
(CC0, Landsat, NASA).

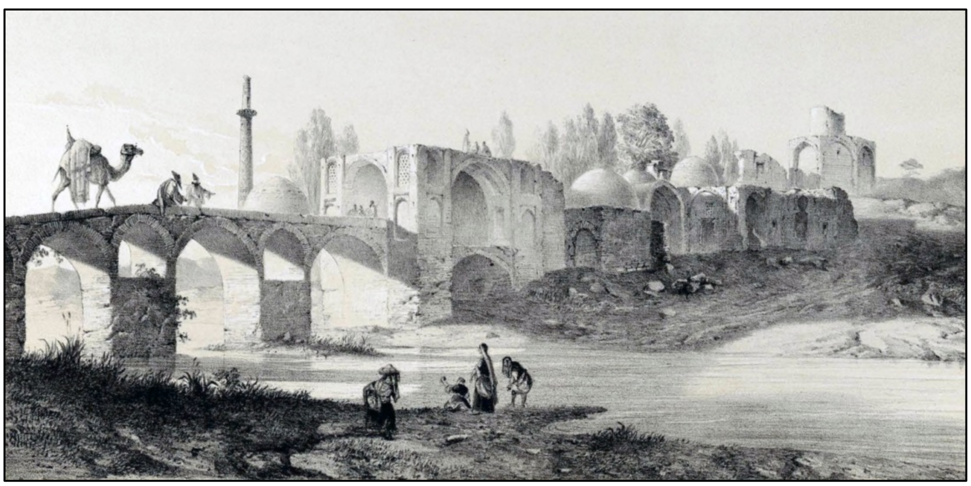
Esfahan is a major oasis city on the Zayandeh at 32°40'N, 51°38'E with a population over two million, famous for its bridges (*pol* in Farsi) among other sites. Pollution from this city is a problem for fishes as detailed below.


Esfahan, Zayandeh River at Si-o-Se Pol
(Si-o-se Pol - Isfahan-Iran-ninara03, CC BY 2.0, Ninara).

Esfahan, dry Zayandeh River at Pol-e Khaju, 30 October 2016,
(Khaju Bridge, Isfahan 01, CC BY-SA 4.0, Bernard Gagnon).

Esfahan, full Zayandeh River at Pol-e Khaju
(Khajoo bridge esfahan (1), CC BY-SA 4.0, Ara9979).

Esfahan, Shahrestan Bridge on Zayandeh River, 2010
(Shahrestan Bridge (Isfahan) 001, CC BY-SA 3.0CZ, Petr Adam Dohnálek).



Esfahan, Shahrestan Bridge on Zayandeh River (Flandin, 1840).

Esfahan, Zayandeh River below Si-o-Se Pol, 21 March 1971, Neil B. Armantrout.

Chahar Mahall and Bakhtiari, Zayandeh River at Horeh
(CC BY-SA 3.0, V. Zahiri).

The Zayandeh basin encompasses about 30,480 sq km and is connected to the upper Karun River basin (which drains to the Persian Gulf) by the Kuhrang Tunnel constructed in 1953 although first proposed in the early sixteenth century (Fitt, 1953; Afifi, 1966; *Islamic Republic*

*News Agency*, 5 February 2002). The Kuhrang River is a Dez River tributary, and thence the Karun River. Two additional tunnels were completed in the late 1990s and early 2000s. The Kuhrang River receives the discharge of *Oncorhynchus mykiss* (rainbow trout) farms which adversely affect water quality in their proximity. Farm discharges spaced at 1,500 m allowed recovery as long as stream flow was good (Fadaeifard *et al*., 2012). The Beheshtabad River is also in the upper Karun River basin, joins the Kuhrang, and is also tapped for the Zayandeh basin. A 177 m high hydroelectric dam at Godar-e Langar (also known as Karun-2 or Masjed-e Soleyman) would also supply piped water to Esfahan 300 km away (Whitley and Gallagher, 1995). The dam has a capacity of 261 million cu m. Gohari *et al*. (2013), referring to the Zayandeh River, considered that water transfer is a system of inadequate water management causing unintended side effects. Demand continues to rise for water resources and efforts to match supply and demand have failed for the last 50 years. Water deficits will occur around the year 2020 (Salemi *et al*., 2005; Salemi and Heydari, 2006).


Chahar Mahall and Bakhtiari, Kuhrang River (CC BY 3.0, cropped, Mehrdad Sarhangi).

Chahahr Mahall and Bakhtiari, Kuhrang dam and tunnel
(Koohrang 1, CC BY-SA 4.0, lightened, Ms96).


Khuzestan, Masjed-e Soleyman Dam
(Lake of Masjed Soleyman Dam …., CC BY 3.0, Hadi Karimi).

Dams also have deleterious effects on a riverine fish fauna and are often stocked with exotic species. Mean annual flow of the Zayandeh is estimated at 1.2-1.45 billion cu m, used mostly for agriculture but an increase in population and industry has necessitated dam construction (Shah Abbas Kabir, Chadegan or Zayandeh River Dam, 88 km west of Esfahan,

capacity 1,450 million cu m, 4,800 ha, height 100 m) and diversion schemes. The dam is an oligo- mesotrophic water body based on phytoplankton studies (Shams and Afsharzadeh, 2009; Narges *et al*., 2019) and water quality was good though decreasing (Khalaji *et al*., 2017; Ebrahimi Dorche *et al*., 2018). The lake was oligotrophic from June to September, and mesotrophic in May, probably due to floods, runoff and drainage of farmlands (Asadian *et al*., 2020). Abbasi *et al*. (2017) noted that over a period of 10 years, an annual average of 180,000 young fish have been released into this dam by the Esfahan Fisheries Department. Annually, 300 t (later 500 t) of fish were taken from the dam by 250 professional fishermen. The fishing season is from August to the end of winter to allow for spring and early summer spawning. The species involved are *Cyprinus carpio* (47.2% of the catch in this survey using gill nets from September to March, released young being 30% of the various species), *Hypophthalmichthys molitrix* (14.0%, young 60%), *H. nobilis*, *Ctenopharyngodon idella*, *Capoeta damascina* (*sic*, possibly *C. coadi*) (35.81%) and *Carassius carassius* (probably *C. auratus*). Details on length frequency and biomass of these experimental catches were also given.

Esfahan, Zayandeh Reservoir
(Chadegan - Zayandehroud Lake - panoramio (1), CC BY 3.0, Alireza Javaheri).

There is also the Hana Dam on the Hana River at Semirom with a height of 35 m and a capacity of 45 million cu m (http://netiran.com/news/IRNA/html931003IRGG04.html) and the Izadkhast dam to the southwest of the Batlaq-e Gav Khuni (*Islamic Republic News Agency*, 2 July 2000). As well as man-made diversions, the upper Zayandeh basin has captured headwaters from systems tributary to the Persian Gulf. The Zayandeh River Dam has reduced the natural flood flows downstream and little water now enters the salt desert.

Plans have been made to transfer Zayandeh River water from the Band-e Cham-e Asseman to Yazd's Shahneh Reservoir by pipeline over a distance of 375 km (*Hamshahri*, *Tehran*, 629:5, 22 February 1995). 78 million cu m of water will be transferred annually and this will decrease the habitat for fishes in the Zayandeh River basin.

Spring flow is at least 1,700 cu m per second, but this drops to 28 cu m per second in

autumn (Oberlander, 1968b). The flow is 1.45 billion cu m annually of which 1.1 billion cu m is used for agriculture, 150 million cu m for industry and the remainder is used as drinking water. Discharge peaks in April with low values in September-October and decreases dramatically downstream after abstraction, evaporation and infiltration (Beaumont, 1981). The Zayandeh can be forded on foot at Esfahan in summer and Buckingham (1829) reported it to be dry. It dried again in 2000, 2001, 2003, 2014 and 2016 under drought conditions, partly through water abstraction upstream for irrigation and partly through aqueducts to other desert cities (Rafsanjan and Yazd) not in the Esfahan basin (Anonymous, 2001a; Foltz, 2002; newspaper reports). Stone (2015) reported the river as mostly dry with many fish species lost.

Water is diverted for irrigation and for domestic and industrial uses. The river is polluted by city sewage, local wastes dumped directly into the river, and industrial wastes, although it is clean in the upriver stretches, and pollution is exacerbated by drought (Moghadam, 1976; Al-Hashimi, 1987; *Tehran Times*, 15 September 1997; Sanayei *et al*., 2009; Fadaei and Gafari, 2014; Izadi Ghorveh *et al*., 2015; Pirali-Zafarahi and Ebrahimi Drache, 2016). The river receives pollution from Esfahan and other urban sources. Biological oxygen demand below Esfahan is listed as bad (Molle *et al*., 2009). 172,000 cu m of industrial pollutants enter the river daily. Pollutants included phosphorus, nitrogen, cadmium, cobalt, copper, iron, lead, manganese, nickel, zinc (with some heavy metal levels above international standards), organic substances, oil products, mineral and organic dyes and the sewage from villages with a population of 900,000 people. Nadim (1977) found the highest mercury levels in fish were 0.19 mg/kg. As the acceptable limit was 0.5 mg/kg, mercury contamination in fish was not considered a problem. Maabodi *et al*. (2011) found high levels of zinc but normal levels of lead in *Carassius auratus*, *Capoeta aculeata*, *C. damascina* (*sic*, possibly *C. coadi*) and *Cyprinus carpio* taken at five stations in the Zayandeh River. Varnosfaderany *et al*. (2010) used benthic macroinvertebrates for a biological assessment of the river, correlating presence/absence with water quality and noting downstream stations were severely polluted from urban wastes and agriculture. Ghane (2014) assessed benthic macroinvertebrate community structure in the upper Zayandeh River and noted the effects of fish farms (*Oncorhynchus mykiss*, rainbow trout) and agricultural activity. Pirali-Zafarahi and Ebrahimi Drache (2016) assessed water quality as bad to very bad from five stations in 2013 drought conditions. Alivand Darani and Chamani (2020) used macrobenthos to during assess water quality in the river and found it was good in spring, while summer and fall were poor, and winter very poor. Karimian *et al*. (2020) found a very high degree of pollution in the sediment at Varzaneh downstream of Esfahan, the mean concentration of arsenic for example (162.9 mg/kg) being about 31 times more than the interim sediment quality guideline standard (5.9 mg/kg) and considerably higher than the similar studies in Iran and other regions of the world. Niknam *et al*. (2020) examined water quality of the Zayandeh River using macrobenthos as a bioindicator and found all stations in all seasons were polluted. Drought during the last decade reduced the flow of water in the river, and water is practically industrial wastewater and sewage.

Ouseley (1819-1823) was an early report on fishes here and he noted numerous small bleak and caught several carp-like fish up to 12-14 inches long (ca. 30-36 cm) in the deeper waters around the bridges over the Zayandeh at Esfahan.

As with all plateau basins, this one also has springs and qanats which contain fishes. Surber (1969) gave some data on total alkalinity and calcium-magnesium hardness in this basin and characterised it as moderately hard.

Fish farms have been developed in Esfahan Province (*Tehran Times*, 31 October 1999).

Thirteen coldwater and 10 warmwater fish farms were expected to yield 490 t of fish, rising to 18 coldwater and 15 warmwater farms by the year 2000 with a yield of 760 t.

Mehdipour (2007) described 32 species of parasites of native and exotic fishes in the Zayandeh River including *Alburnoides bipunctatus* (*sic*, probably an undescribed *Alburnoides* sp.), *Alburnus maculatus* (*sic*, presumably *A. doriae*), *Capoeta aculeata* and *Capoeta damascina* (*sic*, presumably *C. gracilis* or *C. coadi*) (native) and *Carassius auratus*, *Ctenopharyngodon idella*, *Cyprinus carpio* and *Hypophthalmichthys nobilis* (exotic). *Capoeta aculeata* had the most parasite species (14) and *Hypophthalmichthys nobilis* the least (1).

Hamun-e Jaz Murian

The Hamun (= marshy lake, in this instance) is dry for most of the year, but fills with fresh or slightly saline water in winter (Harrison, 1941). Its extent is presumably variable, depending on rainfall. The basin flooded in June 2007, for example, when Cyclone Gonu deposited over 13 cm of rain after several years of drought. The depression is about 30 km by 140 km. It lies at an altitude of about 300-360 m (sources vary), with a still-subsiding depression within the Jaz Murian plain, and is ringed by mountains. Rakhshadi *et al*. (2016) used remote sensing data to assess areas of high protection priority in this basin.

Hamun-e Jaz Murian basin
(IranCatchCen9, CC BY-SA 4.0, Mahdy Saffar)

Hamun-e Jaz Murian, 1 April 2011
(CC0, NASA).

The two major rivers flowing into the Hamun are the Halil (or Haliri) River, known as the Kharan or Zar Dasht River in its upper reaches, which flows from the neighbourhood of Kuh-e Laleh Zar at 4,374 m lying to the northwest, and the Bampur River which flows towards the Hamun from the east but follows a southerly course in its upper reaches (Tipper, 1921). The Bampur River is the type locality for *Cirrhina afghana* var. *nikolskii* (= *Cyprinion watsoni*) and *Garra persica*. The type locality for *Cyprinion kirmanense* (= *C. watsoni*) is probably at Shurabad in the northwest of this basin. The source of the Bampur River lies between 1,000 and 1,500 m. The Halil is a longer river (ca. 390 km) than the Bampur (ca. 315 km) with a stronger and more continuous flow. This river was nearly dry downstream of the Jiroft Dam and there was only minimum flow upstream in 2008 during a drought (Atabak Mahjoorazad, pers. comm., 6 October 2008). There is a discontinuous and intermittent flow in winter. Flash floods are common. Salinity increases from upstream to downstream. The water table is close to the surface, at less than 2 m in places. There is a 130 m high dam on the Halil, the Jiroft Dam 40 km upriver of Jiroft.

Kerman, Halil River in flood at Jiroft, 1 January 2018
(Halil2017, CC BY-SA 4.0, Sina. najmadini).

Kerman, Jiroft Dam on the Halil River
(Jiroft-Dam-Abdolreza-Bahremand, CC BY-SA 3.0, Abdolreza).

A flood water storage dam at Bazman is 37 m high with a capacity of 3.3 million cu m (www.irna.com, downloaded 26 January 2003). Discharge is only 1-3 cu m/second in summer. Floods occur (including an historical one which destroyed Jiroft in 1000 A.D., and one in 1993) and river discharge can reach 800 cu m/second in 15 hours with an 18 m rise in reservoir level in 40 hours and massive sediment transport with turbidity reaching 280 gr/liter (*sic*) (www.stucky.ch/publication/JIRFLOOD.htm, downloaded 19 July 1999). The Bampur River in

late November and early December 1977 was flowing in its upper reaches near Karvandar and around Iranshahr and Bampur but was dry between these two areas. Judging from its width and depth below Bampur it probably did not reach the Hamun by surface flow. Most rain at Iranshahr falls in January and February (15 and 52 mm respectively) with none in the remaining months except for rare summer monsoonal rains (Ganji, 1960). Irrigation and canal schemes in the Bampur basin suffer from erosion and siltation problems as elsewhere in Iran (Borowicka, 1958).

Baluchestan, Bampur River, mostly dry, 1 December 1977, Brian W. Coad.

Habitat of *Cyprinion watsoni* and *Garra persica*, CMNFI 1979-0312,
Baluchestan, Bampur River below dam, 1 December 1977, Brian W. Coad.

The Hamun-e Jaz Murian basin is ringed by much smaller streams draining the surrounding mountains. These are all very small, e.g., the Ughin River was as narrow as 30 cm and maximum depth in pools was about 50 cm when sampled on 4 December 1977 (CMNFI 1979-0326).

Hamun-e Mashkid

The Hamun-e Mashkid (= Mashkel) lies within Pakistan with its western edge on the border with Iran. In this instance hamun means a salt waste and it is fishless. The mountain ranges in this area of Iran are parallel with the Iran-Pakistan border and run in a northwest-southeast direction.

Hamun-e Mashkid basin
(IranCatchEast3, CC BY-SA 4.0, Mahdy Saffar).

The Mashkid River rises to the east of the mountains ringing the Hamun-e Jaz Murian basin and flows east into Pakistan where it receives a right bank tributary, the Rakhshan River, before turning north to flow into the Hamun-e Mashkid. Its total length is ca. 430 km. Two tributaries of the Mashkid within Iran are the Rutak River and the Simish (= Sunish River) which drain the lowlands between Kuh-e Birag (27°35'N, 61°20'E) and the Badamo Range (27°38'N, 62°08'E) from the northwest to enter the Mashkid River southeast of Saravan (27°22'N, 62°20'E). The upper Mashkid River is a small mountain stream, probably with a perennial flow. The lower reaches of this river, and of the Simish, comprise a series of muddy pools of varying size. Some of these pools were isolated and fishless in early December 1977, while larger ones,

perhaps 1 km long, contained some emaciated specimens. In this area fish are found more abundantly in perennially flowing qanat streams.

The Tahlab River and its tributaries drain the eastern slopes of the mountains south of Zahedan (see photograph under “Salt streams and lakes” above). The Tahlab flows in a southeasterly direction into the Hamun over a ca. 160 km course. It was dry between Zahedan and Mirjaveh (29°01'N, 61°28'E) in early December 1977. Mirza and Khurshid (2008) stated that it flows for short periods after rain and has some pools and marshes during the non-rainy season; *Garra rossica* was abundant. The Ladiz River is a short (ca. 80 km) right bank tributary of the Tahlab flowing from Kuh-e Taftan. In its lower reach it was a small stream flowing in the bottom of a deep and wide canyon. The stream banks were white with salt deposits. Mirza and Khurshid (2008) noted that the Tahlab is saline.

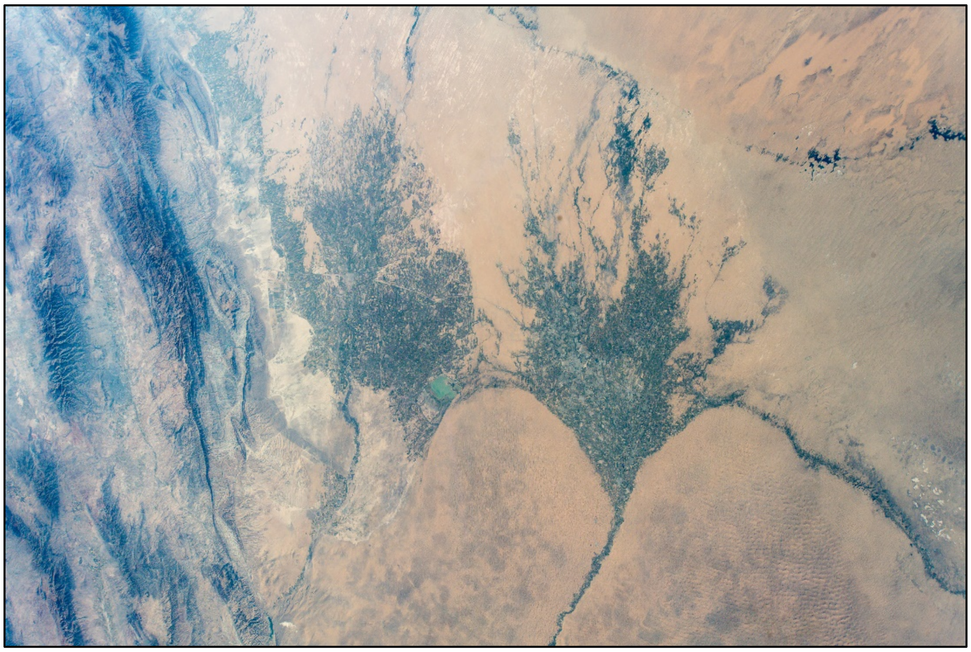
Tedesco *et al*. (2013) listed this basin as one of 20 basins out of 1,010 studied likely to suffer the greatest biodiversity loss due to water availability shrinkage from climate change.

Hari River

The Tedzhen River is the more familiar, international name, sometimes spelled Tejen or Tajan and not to be confused with the Tajan River of the Caspian Sea basin. In Iran this major river is known as the Harirud or Hari River. The Classical name is Arius in Greek or Tarius in Latin.

Hari River basin
(includes more southern tributaries than other maps)
(IranCatchQare0, CC BY-SA 4.0, Mahdy Saffar).

The Hari rises in the Selseleh-ye Kuh-e Baba of Afghanistan and flows west for about 490 km before turning north as the Iran-Afghanistan border for 160 km. Its total length is about 1,100 km. Along with the Hirmand and Aras, this is the only major river entering Iran. At Sarakhs (36°32'N, 61°11'E) it enters Turkmenistan and is known there as the Tedzhen, and is eventually lost in the Karakum desert.

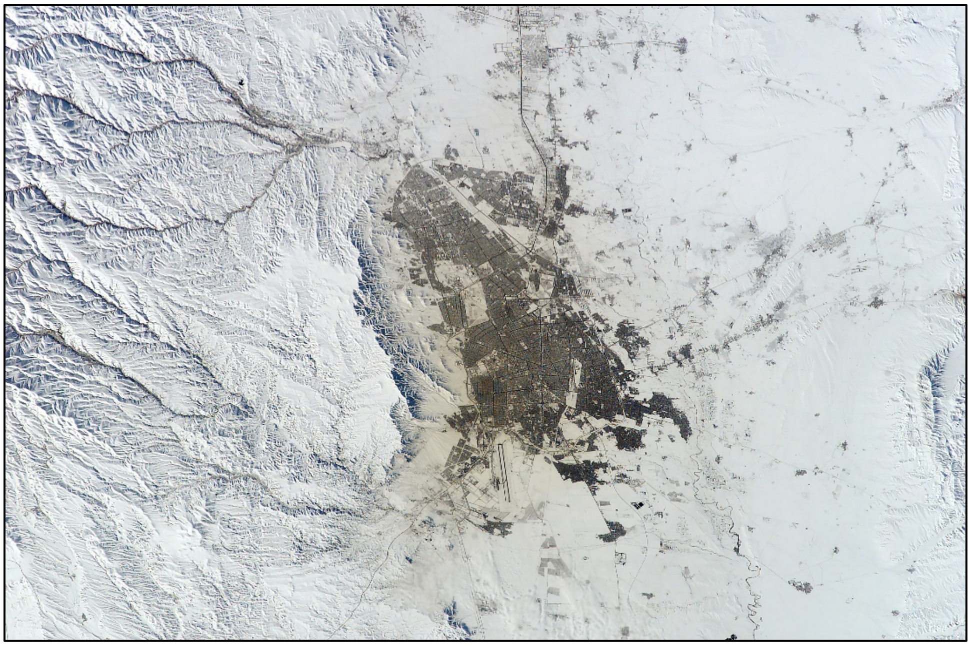


The deltas of the Hari (= Tedzhen) (at left) and Murghab (at right) rivers in Turkmenistan (River end - Fluss aus, CC BY-SA 2.0, Astro_Alex).

The river is usually dry even at Sarakhs (Barthold, 1984) and it dried completely in the year 2000 under drought conditions. Most of the water in the Hari remains in Afghanistan where it is used for irrigation of the Herat valley. Spring floods (March-April) can increase flow ten-fold for short periods of time.

Razavi Khorasan, Hari River, Soheil Eagderi, after Esmaeili *et al*. (2017).

The Jam River is a southern tributary from Iran, draining the mountains around Torbat-e Jam (35°14'N, 60°36'E) and the Kashaf River is a northern Iranian tributary draining past Mashhad from the northern slopes of the Kuh-e Binalud (3,416 m at 36°30'N, 58°55'E) and the southern slopes of the Kuh-e Hazar Masjed (3,146 m at 36°52'N, 59°26'E). The Kashaf is about 310 km long. Its discharge is comparable to, if not as great as, central Zagros streams and is larger than the plethora of minor streams draining the Alborz (Oberlander, 1968b). The downstream Kashaf River was photographed by Mousavi-Sabet *et al*. (2018) and was completely dry apart from reverse flow from the Hari River. The upper reaches of the Kashaf approach those of the Atrak River, a Caspian Sea tributary, and are separated by only a small upfold. This area is very unstable with frequent earthquakes. The catchment area for the Hari basin approaches 45,000 sq km (Pirnia, 1951).



Razavi Khorasan, Kashaf River at Mashhad (lower right)
(STS107-E-5288 - View of Iran, CC0, NASA).

Razavi Khorasan, dry Kashaf River near Hari River
(Kashaf Rud …., in Farsi, CC BY-SA 4.0, Aboozarbahari).

Najafpoor *et al*. (2007) gave a water quality assessment for the Kashaf River and noted its use for water supply, agriculture, fishing and recreation. Pollution from agriculture, and from industrial and municipal wastes at Mashhad, was recorded. Supersaturation from excessive plant life and low night-time levels of dissolved oxygen through respiration could lead to fish kills in the Kashaf. Sheikh *et al*. (2013) showed the presence of the heavy metals chromium, lead and mercury in water and sediments of the Kashaf River. The Kardeh River, tributary to the Kashaf River, has the 67 m high Kardeh Dam 40 km north of Mashhad. Abbasi *et al*. (2016) noted the fauna comprises *Alburnus hohenackeri*, *Capoeta heratensis*, *Carassius auratus*, *Carassius gibelio*, *Garra rossica*, *Hemiculter leucisculus*, *Pseudorasbora parva*, *Hypophthalmichthys*

*molitrix* and *Schizothorax pelzami*. Parasites on this fauna in the Kardeh Dam included *Dactylogyrus* monogeneans, *Trichodina* protozoans, the digenean *Diplostomum spathaceum* as metacercaria, the nematode *Rhabdochona* sp. as larvae, and the cestodes *Ligula intestinalis* and *Diagramma* sp.

The Doosti or Iran-Turkmenistan Friendship Dam on the Hari River south of Sarakhs opened in 2005 and is 78 m high with a reservoir volume of 1,250 mcm. The dam has been stocked with exotics such as *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *H. nobilis* and accidentally *Alburnus hohenackeri* (Jouladeh-Roudbar *et al*. (2016).

Razavi Khorasan, Iran-Turkmenistan Friendship Dam on the Hari River
(CC BY-SA 3.0, Sanchooli).

Bazangan Lake between Mashhad and Serakhs (36°17'N, 60°29'E) is the largest natural lake in northeast Iran with an area of 690,000 sq m and a maximum depth of 6-12 m. It was hyposaline oligotrophic with low phyto- and zooplankton communities, and with a corresponding low diversity of fishes (Ghassemzadeh, 2004). It has suffered from drought in recent years and an increase in salinity from 8.2 g/l in 1973 to 27.2 g/l in 2002 and to 210 g/l in 2015 and is now hypersaline and has a population of brine shrimp (Mohammadyari *et al*., 2015; Mousavi-Sabet *et al*., 2018).

Razavi Khorasan, Bazangan Lake
(CC0, Sanchooli).

A number of minor streams drain northward from the Koppeh Dagh (= Kopet Dagh or Kopetdag) in the west, a range which straddles the border of Iran and Turkmenistan in this north-eastern part of Iran, and from the Hazar Masjed and intervening ranges in the east. These have not been collected by me (but see Mousavi-Sabet *et al*. (2019)). The Iranian tributaries of the Hari have been collected and there is data on the fish fauna from both Afghanistan and the former U.S.S.R. (now Turkmenistan). Coad (1981c, 2014, 2015f) listed and described fishes from Afghanistan, and Aliev *et al*. (1987, 1988), Starostin (1992) and Salnikov (1994) fishes from Turkmenistan. Aliev *et al*. (1987) listed rare and endangered species in Turkmenistan.

There is evidently a strong possibility of exotic species from Turkmenistan entering Iranian waters via the Hari drainage. Fishes, including exotics, are farmed along the basin of the Karakum Canal, a 1,372 km long diversion from the Amu Darya. Some of these exotics can be expected to enter the Hari River basin via its delta and eventually the Caspian Sea basin via the Atrak River through runoff and collector canals (Sal'nikov, 1995, 1998). Potential exotics for Iran from the Karakum Canal include the cyprinoids *Alburnoides* (= *Alburnus*) *taeniatus* (see Jouladeh-Roudbar *et al*. (2016)), *Aristichthys nobilis* (= *Hypophthalmichthys nobilis*), *Aspiolucius esocinus*, *Aspius* (= *Leuciscus*) *aspius iblioides*, *Capoetobrama kuschakewitschi*, *Carassius auratus gibelio*, *Chalcalburnus* (= *Alburnus*) *chalcoides aralensis*, *Ctenopharyngodon idella*, *Hemiculter eigenmanni* (= *H. leucisculus*), *Hypophthalmichthys molitrix*, *Mylopharyngodon piceus*, *Parabramis pekinensis*, *Pseudogobio rivularis* (= *Abbotina rivularis*), *Pseudorasbora parva*, *Rhodeus ocellatus* and *Rutilus rutilus aralensis*. Other species not native to the Hari basin but found elsewhere in Iran are also reported such as *Pelecus cultratus*. *Cyprinus carpio* stocks are a mix of native and Chinese imports. Sal'nikov (1995, 1998) also listed other species which may penetrate the canal eventually. These exotics have a great potential to cause devastation in the native fauna through competition and through genetic

swamping of related taxa. Mousavi-Sabet *et al*. (2018) noted anecdotal reports by local amateur fishermen of the pacu *Piaractus brachypomus* (Serrasalmidae), a South American exotic, in water reservoirs.

The fauna of the Hari basin is found in rivers and streams as well as springs and qanats. Other dams include the Barzou, 40 km north of Shirvan, which is 85 m high with a crest of 325 m and the Shirnin Darreh north of Bojnurd which produces 60 million cu m of water for irrigation (*Iran News*, 17 September 1997).

Berg (1940) placed this basin as a part of his Turkmen District of the Iranian Province (other parts included the Murgab River of Afghanistan and Turkmenistan and northslope streams of the Kopet Dagh in Iran and Turkmenistan). He considered that the Hari River once belonged to the Amu Darya basin of Central Asia.

Kerman-Na'in

The Kerman-Na'in basin extends from Ardestan (33°22'N, 52°23'E) in the north-west to Kerman (30°17'N, 57°05'E) in the south-east. It is an elongate series of small basins combined here for convenience and named for two major towns at the ends of the basin. Its length exceeds 600 km and its maximum width is 175 km. An almost continuous range of mountains, paralleling the Zagros, flanks this basin on the west, while the eastern edge is lower and abuts the Dasht-e Kavir and Dasht-e Lut basins, particularly in the north-east. The Kerman-Na'in basin lies at a similar altitude to the other interior basins, ca. 1,000 m. It may eventually be shown that segments of this basin are more closely related, ichthyologically, with adjacent basins to the west or south, rather than longitudinally through this basin.

Kerman-Na'in basin (northern part)
(includes part of Dasht-e Kavir basin on other maps)
(IranCatchCen4, CC BY-SA 4.0, Mahdy Jaffar).

Kerman-Na’in basin (southern part)
(IranCatchCen8, CC BY-SA 4.0, Mahdy Jaffar).

In the south-east, streams drain the mountains ringing Kerman, such as the Kuh-e Hazaran at 4,420 m (29°30'N, 57°18'E), the Kuhpayeh at 3,142 m (30°35'N, 57°15'E), and the Kuh-e Masahim at 3,600 m (30°21'N, 55°20'E), to a sump just west of Bafq (31°35'N, 55°24'E). These streams bear names such as Namak and Shur and may well be inhospitable to fishes. Several streams between Kerman and Yazd marked prominently on maps were dry in January 1977. Irrigation requirements may have reduced their flow and most of the fishes from this area are to be found in qanats. Qanats have temperatures in this region of 17-21°C in January and have been studied in one village by Smith (1953, 1979).

Around Yazd streams drain the Shir Kuh at 4,074 m (31°37'N, 54°04'E) and the Khar Kuh at 3,512 m (31°39'N, 53°46'E) but there is no major terminal sump. Some of the streams enter the Bafq sump while others drain north to a sump near Na’in (32°52'N, 53°05'E) which also receives intermittent streams from around Na’in.

Intermittent streams from the Kuh-e Karkas at 3,899 m (33°27'N, 51°48'E) drain to a sump near Ardestan but, as in the southern parts of this basin, are not a prominent feature of the landscape and fishes are mostly to be caught in qanats.

The underground water resources of Yazd Province have been examined in a newspaper article (*Hamshahri*, Tehran, 629:5, 22 February 1995) and, although the province is not the same area as the drainage basin outlined here, it is indicative of the underground water resources of this part of Iran. These resources comprised 1,751 subterranean water canals (probably this means qanats), 2,084 semi-deep wells and 897 deep wells with an annual discharge of 1,100

million cu m of underground water. The authorised capacity was 893 million cu m and the excess removal had resulted in an annual drop in the water table of 70 cm. In addition, chemical and biological pollution of groundwater was a continuing problem and these factors too would affect fish survival.

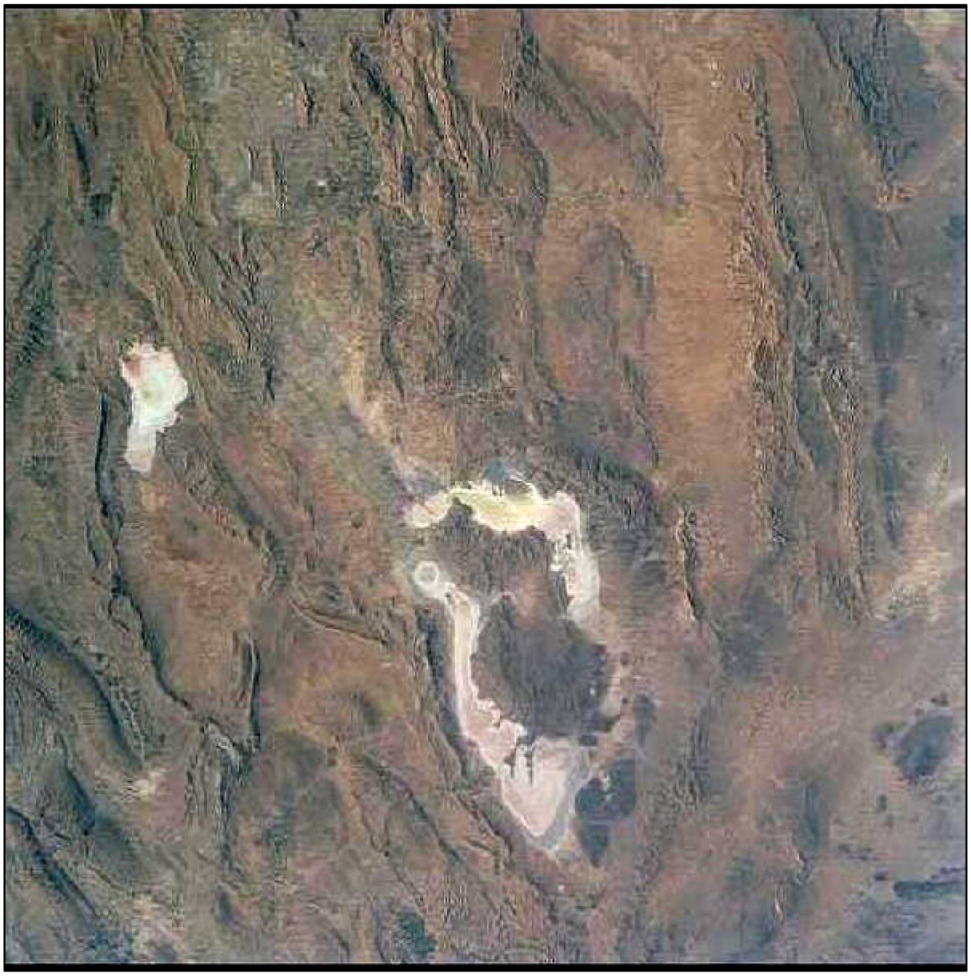
The Chinese major carps are farmed in this area (Kerman Province, e.g.) and Ezatkhah *et al*. (2014) summarised parasites found on these fishes to include *Dactylogyrus*, *Gyrodactylus*, and *Diplostomum* metacercariae, with 39.7% of fish infested. Interestingly, high infestation rates in fall and winter were attributed to immigration of kingfishers to this region.

Much of the fish fauna of the Kerman-Na'in basin appears to be restricted to qanats, although there may be a fauna in high mountain streams not readily accessible by road. The basin is the type locality, in qanats near Yazd, for *Scaphiodon rostratus* (= *Capoeta saadii*).

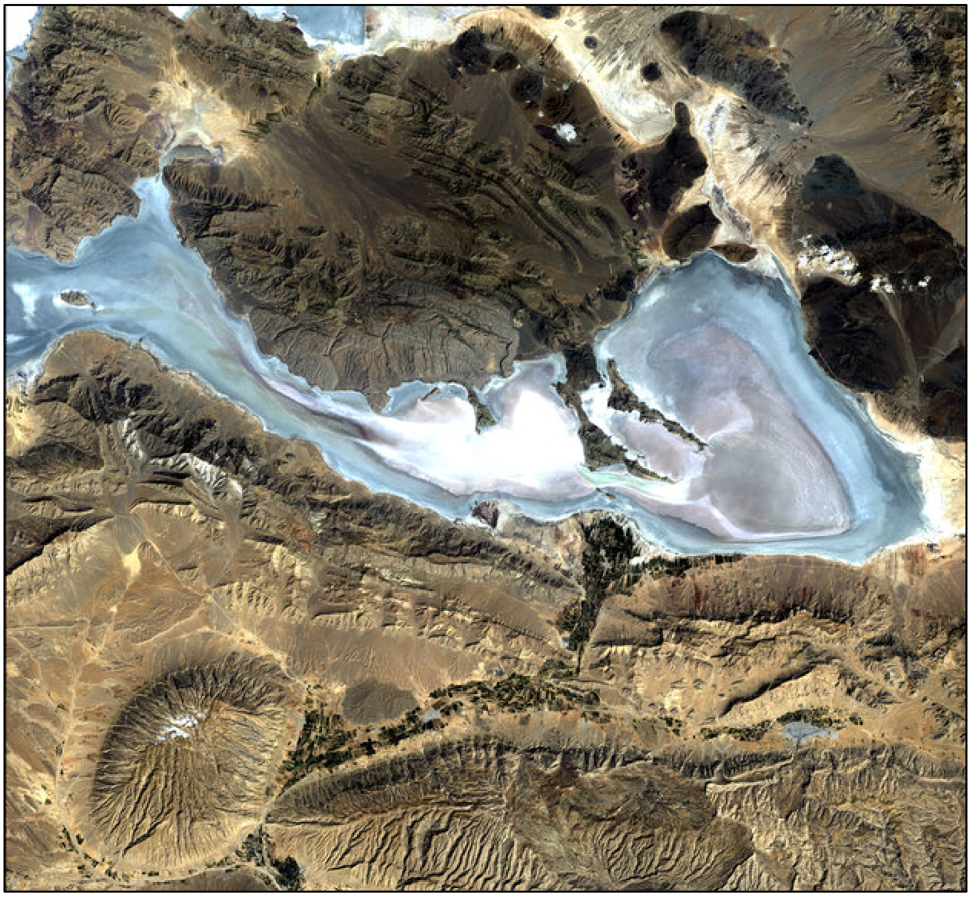
Kor River

This basin occupies 26,440 sq km north and east of Shiraz at a lowest altitude of ca. 1,525 m. Its lowest part is occupied by a chloride lake, the third largest lake in Iran, composed of two parts, a northern basin known as Narges or Tashk and a southern basin known as Neyriz (= Niriz) or Bakhtegan. Neyriz may be used to refer to both Tashk and Bakhtegan. The two basins are not always connected and the southern basin is saltier because major freshwater input is from the north. Löffler (1956, 1957, 1959, 1968, 1981) gave details of this lake. The lake area varies between 1,210 and 2,400 sq km, with a maximum depth of 1.1-1.7 m and a mean depth of 0.5 m. Salinity is 13.7-101.6 g/l and temperatures range from 15°C to 45°C in the shallows. The lake is reported to have dried out completely in 1871, 1933 and 1966 (Cornwallis, 1968a) and in 2000 (*Islamic Republic News Agency*, 26 July 2000). Löffler (1993) considered that this lake may dry out permanently in the near future if abstraction of water from the Kor River for irrigation continued to grow. The drought in 2003 reduced Lake Bakhtegan to a series of puddles. Fluctuations in lake levels affected the freshwater faunas of springs, including fishes, which drain into the lake; high levels swamp the springs with water too saline for fishes to survive. Low levels, however, allowed streams to connect and exchange faunas on the lake bed so they were not as isolated as they might appear. Kafilzadeh (2015) documented organochlorine pesticide residues in water, sediments and fish from Lake Tashk (fish species not specified - "carp", presumably from the neighbourhood of the lake as the lake is fishless). Pesticide levels are likely to pose a risk to aquatic organisms and humans.

Kor River and Lake Maharlu basins
(IranCatchCen6, CC BY-SA 4.0, Mahdy Saffar).



Fars, Lakes Tashk and Bakhtegan (centre) with Lake Maharlu on upper left
(CC0, NASA).



Fars, Lakes Tashk and Bakhtegan
(CC0, NASA).

Fars, Lake Bakhtegan near Neyriz, 29 November 1977, Brian W. Coad.

Fars, Lake Bakhtegan spring, 1977, Brian W. Coad.

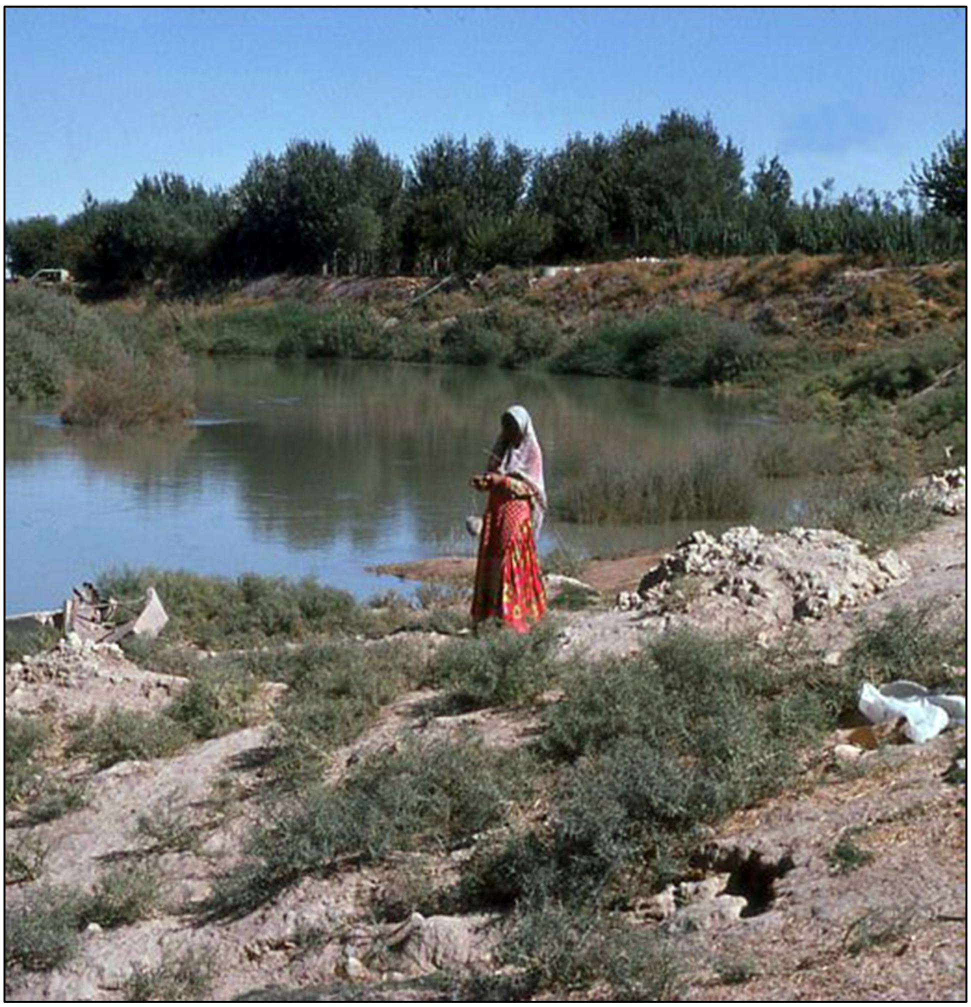
Bobek (1963) suggested that there may have been an outflow from this basin to the Persian Gulf at the south-east corner of the lake which was cut off at the end of the Pleistocene by alluvial fans. However, Krinsley (1970) maintained that any outlet was closed by the late Pliocene. However, Esmaeili *et al*. (2014, 2020) maintained that in the Pleistocene, a Palaeo-Kor River drained from the High Zagros into the Persian Gulf connecting the Kor basin to the Persis basin.

Major rivers are the Kor (= the classical Araxes) and its tributary the Pulvar (or Sivan, Sivand) (= the classical Medus), and also the Marghan River. The Kor is the type locality for *Alburnus megacephalus* and *A. schejtan* (both = *A. sellal*), *Scaphiodon macrolepis* (= *Capoeta macrolepis*), probably for *Leuciscus maxillaris* (= *A. sellal*), for *Scaphiodon amir* and *S. niger* (both = *Capoeta saadii*), and the Pulvar for *Alburnoides qanati*, *Alburnus iblis* (= *A. sellal*), *Discognathus crenulatus* (= *Garra rufa*), *Chondrostoma cyri orientalis* (= *C. orientale*) and *Scaphiodon saadii* (= *Capoeta saadii*). These rivers rise in the Zagros Mountains to the north and north-west and drain to the north-west corner of Lake Tashk. These mountains are high enough (Kuh-e Dinar at 4,432 m and 30°50'N, 51°35'E) to have a snow cover and thus there is a continuous flow throughout the year. However, in summer water does not reach the lake because of the demands of irrigation. Asadi Vaighan *et al*. (2019) found climate change would increase stream flows and decrease nitrate and ammonium concentrations in summer and autumn in this basin. Land use changes in the model were found to have little impact on streamflows but a significant one on water quality.

Kohgiluyeh and Bowyer Ahmad, Kuh-e Dinar range near Yasuj,
19 May 1978, Brian W. Coad.

The catchment basin of the Kor is 9,650 sq km and the dominant discharge is 552.75 cu m/sec upstream of the Dorudzan Dam (Keshavarzi and Nabavi, 2006). The Kor River is about 280 km long. Drainage and irrigation canals run through the basin on the plains at the north end of Lake Tashk. Several springs feed marshes, notably the Lapu'i Marshes, a wetland of 150 sq km to the north-west of the Kor-Pulvar junction, the Zarqan or Zarghan marshes of 4 sq km, an extension of the Lapu'i Marsh (both now severely damaged by construction of a drainage canal as part of the Dorudzan or Daryush-e Kabir Dam at 30°15'N, 52°20'E, on the Kor River), the Gomun, Gumoon, Gumoo or Sangare marshes of 2 sq km at the north-west corner of Lake Tashk and the Sahlabad Marshes of 5 sq km on the south-east coast of Lake Bakhtegan (Cornwallis, 1968a, 1968b). The Band-e Amir or Kamjan Marshes at 29°40'N, 53°05'E are formed at the delta of the Kor River and encompassed about 100 sq km but the Daryush-e Kabir Dam severely restricted the water flow to these marshes. The Gomban Spring or Springs on the northern edge of Lake Tashk has three cyprinoids, *Acanthobrama persidis*, *Alburnoides qanati* and *Capoeta saadii*. Prolonged droughts, uncontrolled abstraction of water by various methods, and the presence of non-native species are the main threats to this habitat (Gholamifard and Kafaei, 2021). *Alburnus sellal* and *Capoeta macrolepis* also occur here. Raeisi and Nejati (2000) gave an average annual discharge of 1,680 l/s and electrical conductivity of about 5,500 microsiemens/cm. The hydrogeology and hydrochemistry data revealed that lake-water intrusion was the main source of salinity.

Fars, Kor River between Pasargad and the Marvdasht Plain, 24 March 1968,
Neil B. Armantrout.



Habitat of *Alburnus sellal* and *Capoeta macrolepis*, CMNFI 1979-0116,
Fars, Kor River at road bridge, south of Marvdasht, 6 October 1976, Brian W. Coad.

Fars, Kor River near Kamfirouz
(Paddies around Kor River, Kamfirouz …., CC BY 3.0, Hadi Karimi).

Fars, Kor River at Feyzabad (CC BY 3.0, H-Karimi).


Fars, Dorudzan Lake
left (CC0, NASA); right (Fars – Dorudzan Lake – panoramio (1), CC BY 3.0, Alireza Javaheri).

The Neyriz Lakes and Kamjan Marshes or Lagoon are a Ramsar Site (World Conservation Monitoring Centre, 1990; Khan *et al*., 1992) although the Kamjan Marsh area may be deleted because of drought and other factors such as rice, wheat and cotton growing, and livestock grazing. The Choghakhur (= Chagha Khur) and Gandoman marshes in Chahar Mahall and Bakhtiari Province will be substituted for the Kamjan Marshes as a listed Ramsar Site (Khan *et al*., 1992). The Gumoon marshes have been partially drained for irrigation and for conversion into aquaculture ponds (Khan *et al*., 1992).

Fars, Kamjan Marsh (CC BY 4.0, cropped, *Tasnim News Agency*, Erfan Samanfar).

The Ghadamgah Spring-Stream system at 30°15'N, 52°25'E and 1,660 m altitude has been described by Esmaeili *et al*. (2007) and is a regional hotspot for biodiversity. The fishes present are *Petroleuciscus* (= *Acanthobrama*) *persidis*, *Alburnoides qanati*, *Capoeta damascina* (= *C. saadii*), *Chondrostoma orientale*, *Cobitis linea* (Cobitidae), *Seminemacheilus tongiorgii*, *Oxynoemacheilus farsicus* (= *O. persa*) (Nemacheilidae), *Esmaeilius sophiae* (Aphaniidae) - all Iranian endemics, and *Alburnus mossulensis* (= *A. sellal*) and *Capoeta macrolepis*. The Ghadamgah Spring-Stream system was analysed in November at three different sites (Esmaeili *et al*., 2007) and showed a water temperature of 17.1ºC, pH 7.28, dissolved oxygen 4.76 mg/l, %

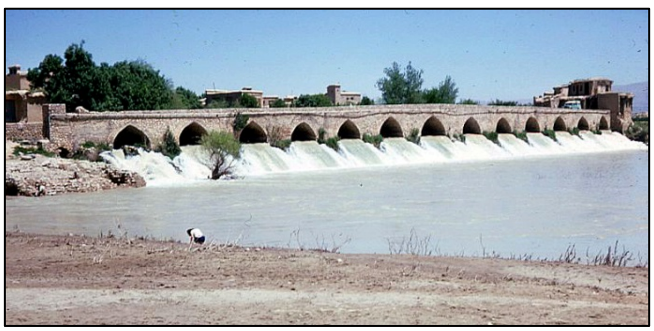
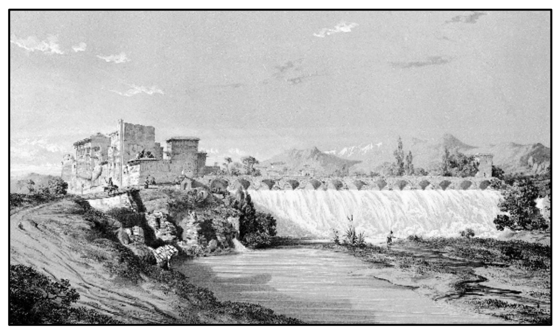
oxygen saturation 60.23, salinity 0.2 (*sic*), nitrate 2.46 mg/l, nitrite 3.33 mg/l, phosphate 1.28 mg/l and ammonium 0.22 mg/l. The climate of the Ghadamgah region is continental with warm summers and cold winters (3.2-31.1ºC), and mean rainfall is 42.04 mm, most of it falling in winter and spring.

Fars, Ghadamgah Spring-Stream system, Hamid Reza Esmaeili.

The Daryush-e Kabir Dam (Dorudzan or Kor Dam) on the Kor River contains 990 million cu m of water, and the reservoir is 24 km long and about 9.5 km wide. Its conductivity is 363 µS compared to Lake Bakhtegan at 105,900 µS and consequently it can support a fish fauna. Djahed *et al*. (2016) summarised water quality of the dam in wet and dry seasons, and ranked it as good. Zamanpoore *et al*. (2016) provided baseline data for measuring the effects of drought on ecological properties and water quality. Baseline data were given as mean annual measures: water temperature 16.7˚C, pH 8.2, dissolved oxygen 7.6 mg/l, ammonium 0.05 mg/l, nitrite 0.004 mg/l, nitrate 0.44 mg/l, phosphate 0.2 mg/l, silicate 7.00 mg/l, biological oxygen demand 2.29 mg/l, chemical oxygen demand 24.49 mg/l, electrical conductivity 720 µs/cm, total dissolved solids 457.67 mg/l, calcium hardness 61.3 mg/l and magnesium hardness 20.23 mg/l. Main different parts of the lake showed a quite different composition of fish species. An epidemic occurence of the crustacean ectoparasite *Lernaea cyprinacea* among most fishes was another important finding. Zamanpoore and Yaripour (2017) described the species composition and spatial distribution of fishes in the dam in winter 2010 and autumn 2011, the cyprinoid fishes being *Alburnus mossulensis* (= *A. sellal*), *Capoeta aculeata* (= *C. macrolepis*), *Capoeta damascina* (= *C. saadii*), *Carasobarbus luteus*, *Carassius gibelio*, *Cyprinus carpio* and *Hypophthalmichthys molitrix*, the last three being exotics. Paighambari *et al*. (2020) also listed the fishes in this dam from winter 2017 to summer 2018, adding *Hypophthalmichthys nobilis* to the list. This work also noted that a high number of carps are released into the dam lake yearly and several fishing cooperatives harvest the fish. The highest Shannon-Wiener and Simpson indices (measures of diversity) were in spring and winter. *Cyprinus carpio* and *Planiliza abu* (abu mullet) were the most effective species causing changes

in seasonal fish abundance and diversity. Zamanpoore *et al*. (2021) sampled fish from three staions in the dam in late summer and mid-spring 2015. The fish community comprised *Alburnus mossulensis* (= *A. sellal*), *Capoeta aculeata* (= *C. macrolepis*), *C. damascina* (= *C. saadii*), *Carasobarbus luteus*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *H. nobilis* and the mugilid *Planiliza abu* (note no mention of a *Carassius* species). Length-weight equations indicated proportionate growth except for *H. nobilis* which lacked sufficient material. Condition factor was higher than 1.0 in all species confirming proper somatic growth. Acceptable lengths for catches were calculated for *A. sellal* at 14 cm, *C. macrolepis* at 24 cm, *C. saadii* at 24 cm, *C. luteus* at 21 cm, *C. carpio* at 30 cm, *H. molitrix* at 76 cm and *P. abu* at 14 cm, catch per unit efforts were calculated for *A. sellal* at 1,260 g, *C. macrolepis* at 800 g, *C. luteus* at 172 g, *C. carpio* at 2,064 g, and *P. abu* at 6,324 g, and maximum acceptable catches were *A. sellal* at 2,643 kg, *C. macrolepis* at 1,367 kg, *C. luteus* at 293 kg, *C. carpio* at 3,690 kg, and *P. abu* at 12,309 kg. Continuous climate change and eutrophication emphasised the need to assess and monitor the fish populations.

Band-e Amir on the Kor River is a diversion dam over 1,000 years old and also provides a small reservoir habitat for fishes (Houtum-Schindler, 1891).

Fars, Band-e Amir, 28 November 1977, Brian W. Coad and 1840, E. Flandin.

Habitat of *Acanthobrama persidis* and *Alburnus sellal*, CMNFI 1979-0342,
Fars, Kor River below Band-e Amir with pelicans, 22 November 1977, Brian W. Coad.

Fars, Kor River near Faizabad downstream from Band-e Amir
(CC BY 3.0, H-Karimi).

At least three other dam sites have been proposed in this basin (Tang-e Boragh (now the Molla Sadra Dam), Tang Bulak and Ghaderabad (= Qaderabad)). The Molla Sadra Dam has been constructed on the Tang-e Boragh waterfall at the upstream reaches of Kor River. Torabi Haghighi *et al*. (2012) noted how Kor River conditions and fish habitat were altered by dam construction. The Sivand Dam, on the Tang-e Boragh or Bolaghi, would affect the flow of the Pulvar River but was opposed on archaeological grounds (www.netiran.com, downloaded 4

October 2004). It was completed in 2007. A series of six ancient diversion dams are being rehabilitated along the Kor River (Zand *et al*., 2007), for flood control and diversion of water to farmland. These naturally affect the habitat for fishes and some fish may be lost in drying fields.

Fars, Tang-e Boragh (CC BY 3.0, Hadi Karimi).

Surber (1969) gave some spot data on pH, total alkalinity, calcium-magnesium hardness, chlorides and free $CO_2$ in this basin. Water is relatively hard. Concentrations of total dissolved solids vary between 202 mg/l and 436 mg/l in the rivers compared to a range of 333-6,937 mg/l in the Persis basin. Shayestehfar *et al*. (2008) summarised physico-chemical properties of the Kor River over four seasons at three stations, showing wide seasonal and site variation. The water temperature range was 5.0-36.7°C, dissolved oxygen 1.3-11.73 p.p.m., biological oxygen demand 0.25-112.6 p.p.m., chemical oxygen demand 1.1-196.0 p.p.m., total nitrogen 2.4-83.7 mg/l, total hardness 35.9-348.5 mg/l, pH 7.06-8.7, total alkalinity 98.4-398.0 mg/l, total acidity

0.1-0.45 mg/l, total solids 11.7-536.0 mg/l, and water current 13.3-81.4 l/sec. Rasouli *et al*. (2012) examined 60 water samples from the Kor River and 90 water samples from wells in the Kor-Sivand (= Kor-Pulvar) basin and provided water quality assessments.

Kaftar (or Shakam or Shad Kam) Lake and Wetland at 30°34'N, 52°47'E is at ca. 2,300 m in the Zagros Mountains northeast of Shiraz. The wetland is one of the sources for the Sivand or Pulvar River. It occupies 4,700-4,800 ha (500 ha in Khan *et al*. (1992) presumably an error for 5,000 ha) and is a shallow, semi-permanent freshwater lake which can dry out completely in summer and is frozen over in winter. The annual mean water temperature is 14.4°C, the mean maximum 23.5°C and the mean minimum about 2°C (B. Jalali, pers. comm., 1999); and Nowrouzi and Valavi (2011) gave various physicochemical parameters. Lake water has been proposed for irrigation usage in the past and a proposed earthen dam would reduce the lake area by half (Scott, 1995). It has a mixed ichthyofauna of native species and exotics (the latter being *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *H. nobilis* and *Pseudorasbora parva* after Barzegar and Jalali (2002) and Rahimi and Tabiee (2013)). The fishes recolonise from springs and the main river entering the lake and are also stocked.

Fars, Kaftar Lake
(Iran – Fars – Eqlid – Kaftar Lake – panoramio, CC BY 3.0, lightened, Alireza Javaheri).

The Kor River basin also contains qanats. Some of these flank the Pulvar River, for example, and serve to bring water to fields above the incised river bed. The type locality of *Alburnoides qanati* is eponymous of a Pulvar River qanat.

Pollution in this basin was recorded by Merchant and Ronaghy (1976), where industry discharged waste untreated into surface and ground waters. Waste from a sugar mill killed one million fish in 1994 and a further 500,000 fish died in 1996 from industrial waste (www.iran-e-azad.org/english/noi/noi-83.html or *News on Iran*, 83, 15 November 1996). A fish kill was reported from the Pulvar River in 1978, polluted by wastes from a food factory (Coad, 1980b). Peritore (1999), Moussavi and Saber (1999), Ebrahimi and Tehranifard (2011a, 2011b) and Sheykhi and Moore (2012, 2013) recorded the Kor River receiving organic wastes from animal

processing plants, ammonium and mercury from petrochemical complexes, agricultural and municipal wastes, and such heavy metals as arsenic, cadmium, chromium and lead from electronics manufacturers and other industries. Heavy metals induced pathological changes in cyprinoid fish organs and disrupted reproductive hormone secretions. Ebrahimi *et al*. (2008) and Taherianfard *et al*. (2008) reported lead and mercury levels in *Cyprinus carpio* and *Capoeta* spp. to be less than the maximum allowable by the European Union but still of concern. Ebrahimi and Taherianfard (2010a, 2010b, 2011a, 2011b), however, found that levels of arsenic, cadmium, lead and mercury for these species were higher than permissible for human consumption.

Channels started in 1981 to provide more agricultural land drain through the Kamjan Marshes to Lake Tashk and the Kharameh Marshes to Lake Bakhtegan. Much of the marsh habitat was destroyed. The Gumoon Marsh was drained for agriculture and fish ponds.

Miller (1985) reported on deforestation in this part of Iran during the fourth to second millennium B.C. Even marsh areas were probably treed before demands for charcoal and construction materials increased. The fish faunas must have adapted to increased insolation and any species sensitive to higher marsh and stream temperatures would become less common.

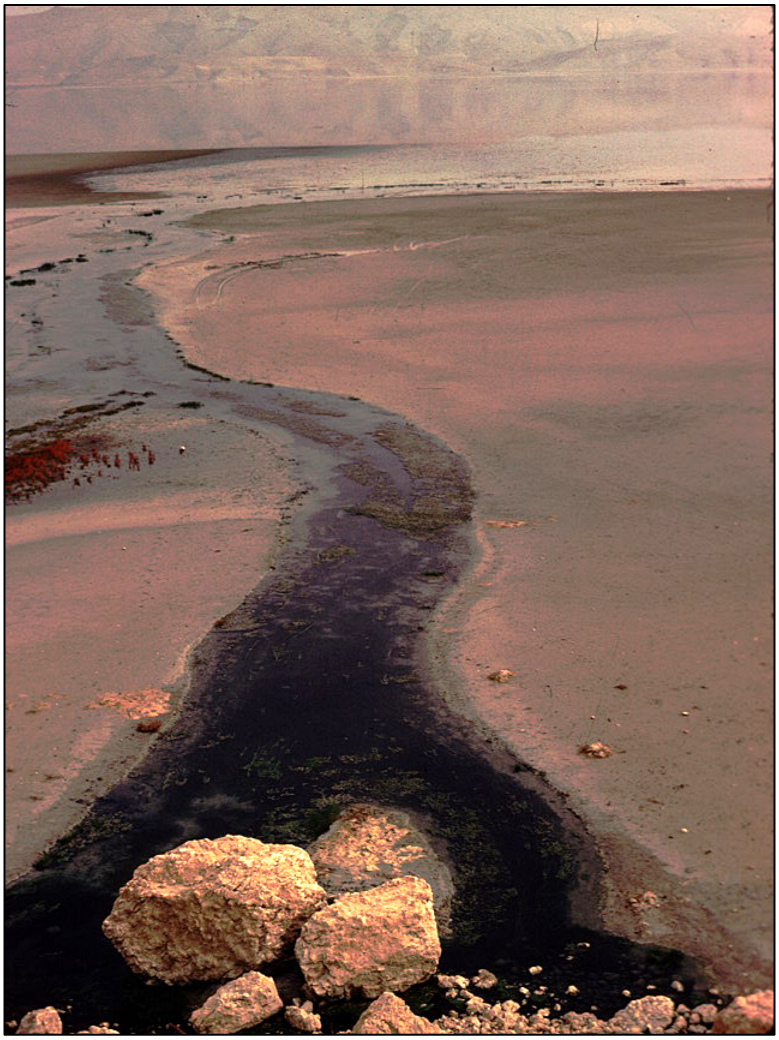
Tedesco *et al*. (2013) listed this basin as one of 20 basins out of 1,010 studied likely to suffer the greatest biodiversity loss due to water availability shrinkage from climate change.

Lake Maharlu

The Maharlu basin is the valley of Shiraz (29°36'N, 52°32'E) and encompasses about 4,100 sq km. Lake Maharlu is at an altitude of about 1,460 m, has an estimated average area of 220 sq km, is 28 km long and 10-15 km wide, has a maximum depth variously cited as 0.5 and 3 m, a salinity of 124‰ or 304.95 g/l, and is fishless because of the high salt content.

Fars, Lake Maharlu, salt extraction, April 1976, Brian W. Coad.

The lake dries out completely, in 1967 for example (Cornwallis, 1968a) as well as more recently (Zamanpoore *et al*., 2019). The latter work summarises chemical and physical properties of the lake and references other works. The lake is fed by minor streams and springs around its margin.



Fars, Lake Maharlu spring, penetrated by salt water and lacking cyprinoids (the aphaniid *Esmaeilius persicus* was present), 17 February 1976, Brian W. Coad.

The Khoshk River flowing through Shiraz is dry for much of the year or composed mostly of polluted wastes from businesses, domestic sources, industry and agriculture (Kafilzadeh *et al*., 2007; Karami and Gahmani, 2008; Khakzand *et al*., 2013). Elevated levels of the heavy metals cadmium, chromium, copper, lead and zinc were due to anthropogenic activities while nickel was mainly of natural origin (Salati and Moore, 2010). Koukabi and Aminzadeh (2009) and Pourjafar *et al*. (2010) discussed improving this urban river through landscape design.

Fars, Khoshk River in Shiraz, winter 1976, Brian W. Coad.

The basin also has a number of qanats. Stream temperatures vary between 8°C in January to 32°C in June while qanats can be warm even in winter, e.g., at Sarvestan (29°16'N, 53°13'E, CMNFI 1979-0162) on 1 December 1976 a qanat was 25°C. Surber (1969) gave some spot data on pH, total alkalinity, calcium-magnesium hardness, chlorides and free $CO_2$ in this area.

Fars, Lake Maharlu, red with *Dunaliella* algae, lakes Tashk and Bakhtegan at right (CC0, NASA).

Fars, Lake Maharlu
(ISS051-E-50720 - View of Iran, CC0, colour, contrast and tone adjusted, NASA).

Fars, Lake Maharlu, red with *Dunaliella* algae
(Maharloo Lake 20190619 17, CC BY 4.0, Hadis Faghiri).

Fars, Lake Maharlu, 1976, Brian W. Coad.

The basin is separated by only a small rise from the Mond River of the Persis basin, but is treated separately here because fish collections have been focused on this valley as Shiraz is the major city of southern Iran, and there is an endemic species present, the aphaniid *Esmaeilius persicus*.

Major fresh to brackish springs and their associated marshes (Ab-e Paravan (2.5 sq km), Barm-e Shur (1.5 sq km) and Soltanabad (7 sq km)) are concentrated at the northern end of the lake (Cornwallis, 1968a). Larger springs have pools which are about 2 m deep and reed beds of *Phragmites* and *Typha*, some of which are cut. Livestock grazing occurs. Amphibious tanks were tested in Barm-e Shur in the 1970s, stirring up anoxic bottom mud and leading to a fish kill.

Habitat of *Carasobarbus luteus* and *Garra rufa*, CMNFI 1979-0018,
Fars, Barm-e Shur, Lake Maharlu, 26 January 1976, Brian W. Coad.

Numerous small springs around the lake are isolated from one another by the intervening hypersaline water. Lake levels fluctuate markedly and allow streams to meet on the exposed salt flat when the water level is low. At high levels, salty water invades the lower springs and eliminates their fishes, which only recolonise when the lake level falls again and connection is made with a stream from a spring which was above the last rise in lake level. One spring had a salinity of 34‰ at the source when the lake had risen to invade the spring. Another spring was replete with aphaniids at 144‰. Temperature on 8 June 1976 at one spring was 27°C at the surface and 32°C on the bottom, at about 1 m depth (CMNFI 1979-0112).

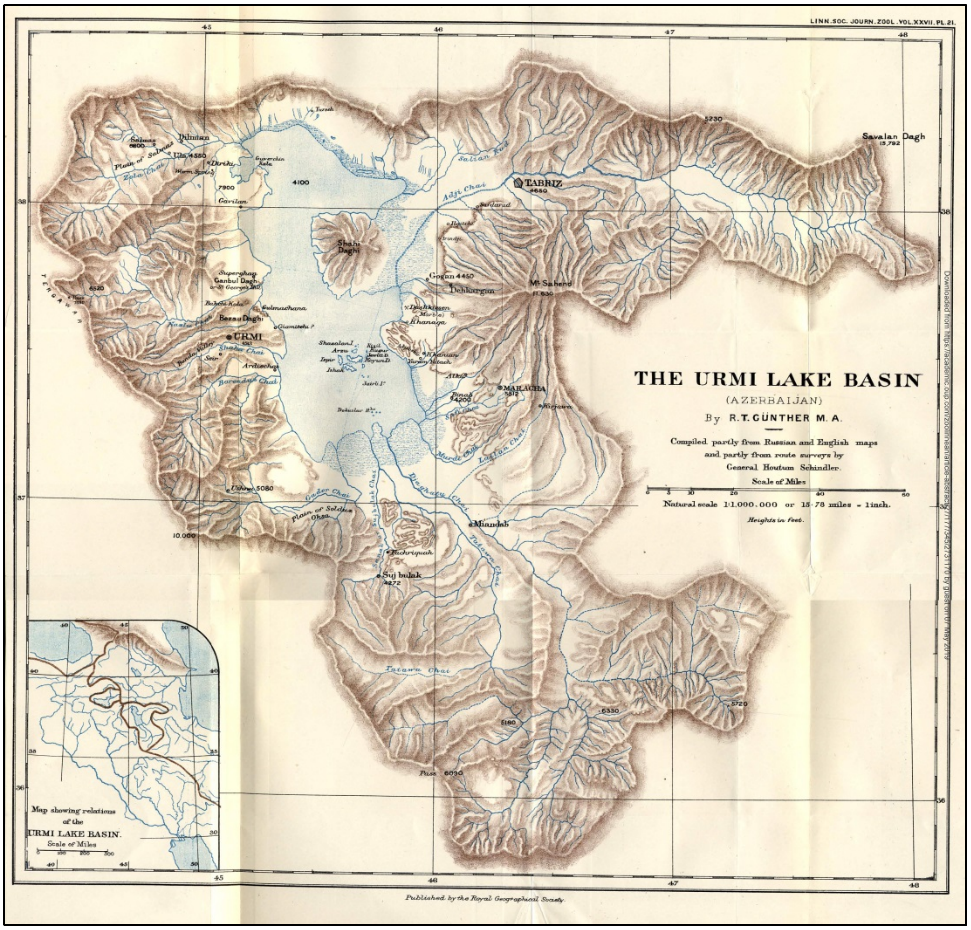
Tedesco *et al*. (2013) listed this basin as one of 20 basins out of 1,010 studied likely to suffer the greatest biodiversity loss due to water availability shrinkage from climate change. Fotouhi *et al*. (2014) carried out a risk assessment of drying of the lake and found increased temperature, variation in land use, drop in static level of wells and drying up of springs were the most important hazards. Gholamifard and Kafaei (2017) noted that exotic Chinese carps are fish farmed in this basin, especially at the northern lake margin, and there are accidentally introduced species too. Drought and over-harvesting of groundwater resources threaten native species as water is used for fish farming. Fish farmers use seasonal drying of native habitats as a means of eliminating native species, as well as direct removal, and this could well lead to extinction of most, if not all, native species.

Lake Urmia

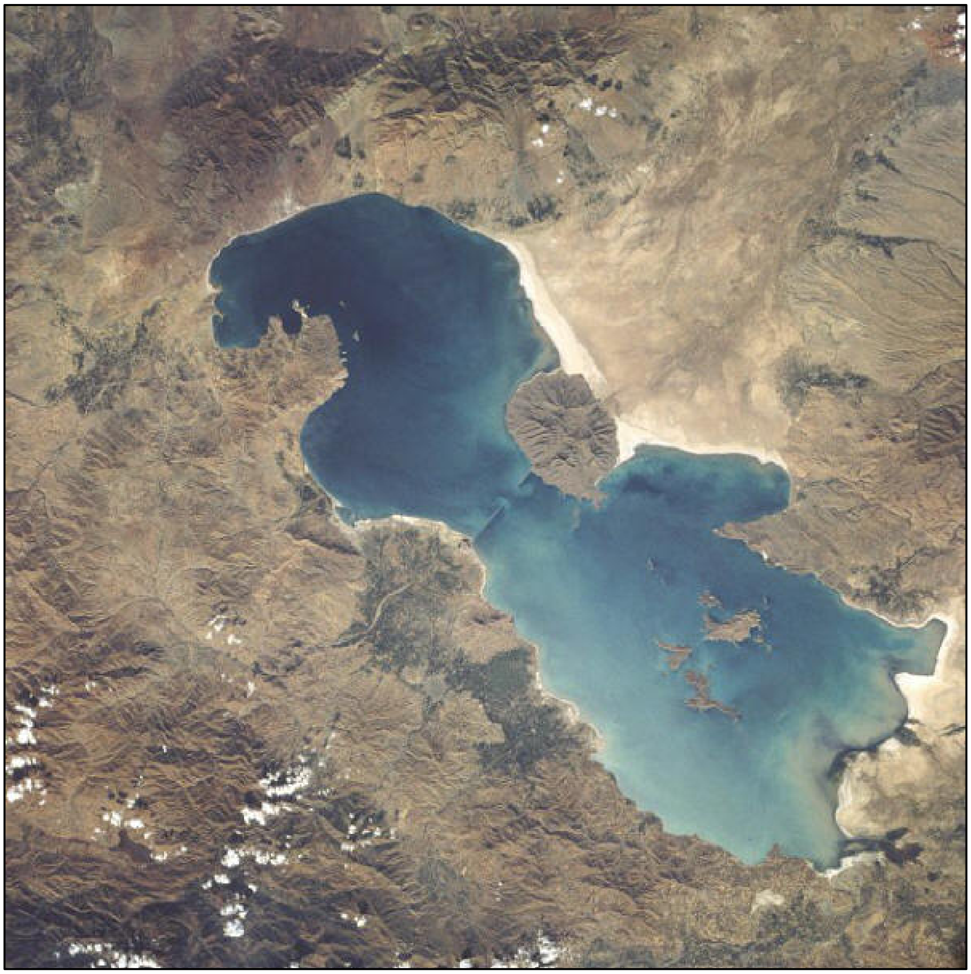
Lake Urmia (= Orumiyeh, Reza'iyeh, Uromiyeh, Urmi, Urumiyeh, or Darya-e Shahi, the classical Lacus Matianus) lies in north-west Iran and was the only Iranian lake large enough to appear on general maps of the world. It was the largest lake in the Middle East and was the sixth largest salt lake on earth. The Assyrian name "Puddle of Water" derived from Urmia is now apt through the ongoing desiccation, the Old Persian name Chichast ("glittering") referenced the mineral particles suspended in the lake water and found along its shores, and its medieval name Kabuda or Kabodan was from the word "azure" in Persian.

Lake Urmia basin
(IranCatchUrm0, CC BY-SA 4.0, Mahdy Saffar).

Its ichthyofaunal diversity (in tributaries) has been reviewed by Ghasemi *et al*. (2015), an overview of water resources was given by Hashemi (2008), of agricultural water use with details of rivers, droughts and dams by Faramarzi (2012), of water management, dams and drought by Zarrineh and Azari Najaf Abad (2014), of irrigation development and climate change effects on the lake level by Beygi (2015), of efforts to save and restore the lake (Agh, 2016; Arab and Tajrishi, 2016), of developing a comprehensive approach for the determination of environmental water requirements of surrounding wetlands (Yadegarlu, Dorgeh Sangi, Kanibarazan and Gharah Gheshlagh - see below) (Sima and Ganjali, 2016), and of the hydrological cycle by the Japan International Cooperation Agency *et al*. (2016). Lotfi (2018b) gave a general overview. This lake is a Ramsar Site and includes Urmia National Park. Brackish marshes in the northeast, northwest and southern shores support some fishes as do tributary rivers but the lake itself is too salty.




Lake Urmia basin, after Günther (1899).



Lake Urmia, October 1984
(CC0, NASA).

Lake Urmia, 10 April 2021
(CC BY 4.0, cropped, Tasnim News Agency, Mojtaba Esmaeil Zad).

Lake Urmia shoreline
(Shoreline of Lake Ourumiyeh - Western Iran - 01…., CC BY-SA 2.0, Adam Jones).

Lake Urmia lies at about 1,275-1,300 m (accounts vary), was about 128-149 km long and 40-60 km wide. This thalassohaline lake had a surface area of 4,750-6,100 sq km, a volume of 29.4 cu km, a mean depth of 4.9-6.0 m, a maximum depth of 16 m, and a temperature range of -1.3-27.5°C. Lake level can rise as much as 2 m in one season, as it did in the winter of 1968-1969. It is a sodium chloride-sulphate system with a salinity up to 340.0 g/l (but mostly 217-235 g/l and recently to 400 g/l) and consequently is fishless (Abich, 1856; von Seidlitz, 1858; Rodler, 1887; De Mecquenem, 1908; Plattner, 1955; Vladykov, 1964; Kelts and Shahrabi, 1986; Ghaheri *et al*., 1999; www.neda.net/inwm/no.6/english/geology/geology01.html, downloaded 10 July 2000; Van Stappen *et al*., 2001; Eimanifar and Mohebbi, 2007; Karbassi *et al*., 2010). Initially the lake was probably fresh (Admiralty Naval Staff, 1918). A causeway has divided the lake into two parts since 1989; a gap allows a limited exchange between the two parts. Its drainage basin approaches 57,000 sq km (or 51,786 sq km, authors differ) and the lake is the terminal basin for a number of streams and rivers. A total of 21 permanent or seasonal rivers as well as 39 periodic ones discharge into the lake. Annual inflow is 6,900 million cu m (Ghaheri *et al*., 1999). During spring runoff, a freshwater plume covers large areas over the saline lake near river mouths. Rivers and streams in this basin are suffixed by chai or chay so adding river is a tautology. They may be referred to as river or chay, or both since this is how they appear in the literature or for clarity. The locations of the Ocksa and Urmi rivers are discussed under *Acanthobrama urmianus,* the type localities for this species. Prominent perennial streams include the Zarrineh (= Golden) River (302 km long) entering from the south and draining part of the northern Zagros with a range in discharge of 10-510 cu m per second with the Simineh River (= Tata’u or Tatavi) (200 km, and a type locality of *Alburnus atropatenae*) as a major tributary, the mineralised Talkheh (= Bitter River, also called the Aji or Agi Chay) (276 km) from the east draining the flanks of Kuhha-ye Sabalan at 4,810 m (38°15'N, 47°49'E) and Kuh-e Sahand at 3,710 m (37°44'N,

46°27'E), and the smaller streams from the west such as the Zowla (= Zola) Chay or River (84 km, and the type locality of *Alburnus ulanus*), Nazlu Chay (85 km, and a type locality of *Alburnus atropatenae*, Shahr Chay (= Shaher, Shahar, Shahr, i.e., City River flowing through Urmia) (60-70 km), Baranduz Chay (70 km, and its tributary the Qasemlu, the type locality of *Alburnoides petrubanarescui*) and Gadar (= Qader) Chay (100 km, and the type locality of *Leuciscus gaderanus* (= *Alburnus ulanus*)) (Günther, 1899). The main freshwater source for Lake Urmia is the Zarrineh River (>50%) with the Simineh and Qader rivers supplying 35% of the inflow (Zarrineh and Azari Najaf Abad (2014) - N. Zarrineh appropriately named). Radkhah *et al*. (2020) found temperature, altitude and water velocity were the factors affecting fish diversity in the Zarrineh River while depth, velocity and discharge were the environmental factors affecting abundance of fish. Radkhah *et al*. (2020) summarised the Zarrineh River ichthyofauna from collections at seven stations finding the cyprinids *Barbus lacerta* (= *B. cyri*), *Capoeta capoeta* and *Carassius gibelio*, and the leuciscids *Alburnus atropatenae* and *Squalius turcicus*. The fish populations of the Zarrineh River declined dramatically due to such anthropogenic activities as overfishing, pollution (industrial, agricultural, urban), sand and gravel extraction, dam construction, and introduction of exotic fishes over the last decade (almost half the fish fauna was exotic). Among the human factors, the effect of overfishing, especially unauthorised fishing was a major threat.


West Azarbayjan, Shahr Chay below dam
(Urmia Dam …. in Farsi, CC BY-SA 3.0, Auoob Farabi).

West Azarbayjan, Zarrineh River at Miandoab
(Miandoab Historic Bridge, CC BY 3.0, Mehrdad Sarhangi).

West Azarbayjan, Simineh River in Bukan
(Siminehroud-in bukan, CC BY-SA 3.0, cropped, re-oriented, Zartoshkurd).

The Talkheh River has a hardness of 820 mg/l according to Surber (1969), who also gave values of total alkalinity and calcium-magnesium hardness for a number of streams and lakes around Tabriz. The Talkheh floods extensively in the spring and forms large marshes. There were plans to divert the Talkheh away from the alkali lands for agricultural uses. Most streams were relatively hard like the Talkheh although some were soft such as the Basmenj Chay draining Kuh-e Sahand at 70 mg/l. The Simineh River spring run-off can reach as much as 57,000 l/second. Water abstraction for agriculture resulted in a return flow of degraded water quality. The Nazlu Chay was polluted from sewage, industry and agriculture, but also suffered from sand

and gravel extraction which harmed aquatic plants, clogged fish gills, destroyed spawning beds and disrupted feeding (Saatloo *et al*., 2014). Kourandeh (2012) assessed the water quality of the Aji (= Talkheh) Chay and found downstream human and industrial pollution. Average values for eight stations were 7.1-15.2°C, pH 7.8-8.3, phosphate 0.53-2.66 mg/l, nitrate 1.72-3.59 mg/l, biological oxygen demand 2.66-33.35 mg/l, dissolved oxygen 4.0-10.5 mg/l, total dissolved solids 350-6,250 mg/l, turbidity 12-38 NTU (Nephelometric Turbidity Units) and faecal coliform 574-619 MPN/100 ml (MPN = most probable number).

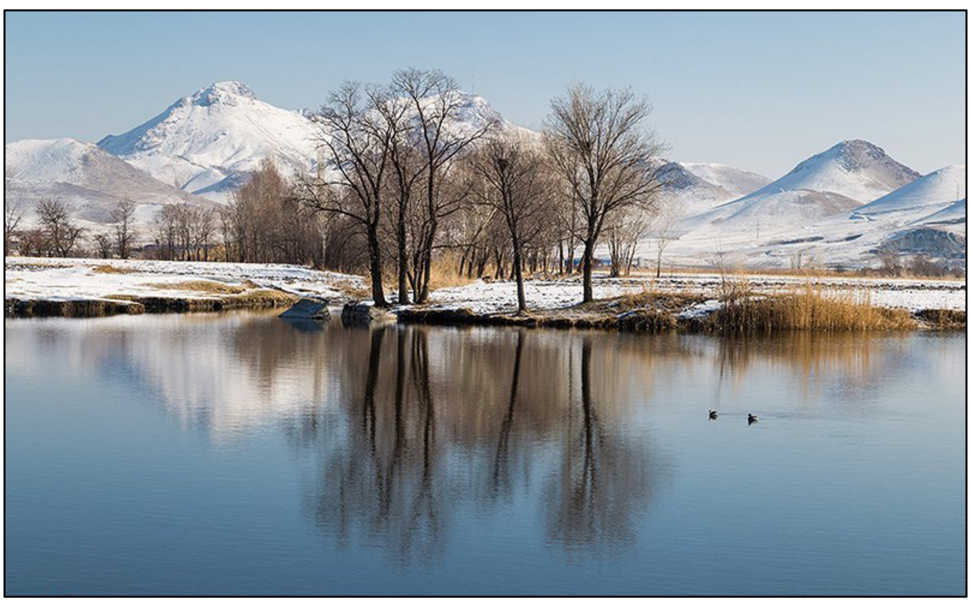
East Azarbayjan, Aji or Talkheh River, Hamid Reza Esmaeili.

East Azarbayjan, Aji River showing habitat alteration, Hamid Reza Esmaeili.

River flows in this basin have decreased in recent years and Khalili *et al*. (2013) attributed this in part to climate change, increasing air temperatures changing precipitation to rain rather than snow, where rivers depended on snow melt water for their flow in warmer weather. This undoubtedly obtains for all rivers fed from the higher Alborz and Zagros mountain chains. Kanani *et al*. (2019) found that runoff reduction in the Lighvan (= Liqvan) Chay was due 65-84% to human factors and 16-35% to climate factors in all models.

Lake Qowpi (= Kobi, Kopi, Ghopi or Daryacheh-ye Qowpi-ye Baba `Ali) is a Ramsar Site lying at 36°57'N, 45°52'E and 1,240 m altitude in this basin. It is south of Lake Urmia and northeast of Mahabad. It comprises the fresh to brackish intermittent lake and associated but discontinuous marshes of about 1,200 ha. The endorheic lake is shallow with a maximum depth of 1.5 m and a mud bottom. It is fed by precipitation and springs, and when full floods marshes to the north. It freezes over in winter. The lake is eutrophic and has reedbeds of *Phragmites communis* and abundant submerged vegetation. Livestock grazing and wildfowl hunting occur.

The Shur Gol and the Yadegarlu and Dorgeh Sangi endorheic lakes are at 37°00', 45°26-35'E south of Lake Urmia and northwest of Mahabad at 1,290 m are also a Ramsar Site comprising 2,500 ha of lakes and associated marshes. They are fed by precipitation, springs and small streams. Shur Gol at 2,000 ha is surrounded by the Hasanlu or Hassanlu Marshes. Its water is brackish to saline. The eutrophic marshes flood in fall and winter and have abundant submerged vegetation. Yadegarlu is a shallow freshwater lake of 350 ha with abundant submerged vegetation and a surrounding of eutrophic sedge marshes. It may dry out in summer and construction of the Hasanlu Dam exacerbated water loss. The lake apparently suffered in the Iran-Iraq war (Jones, www.ramsar.orib_dir_2_3.htm, downloaded 4 April 2000) and may be deleted as a Ramsar Site. A fish kill in July 1999 occurred in the Yadegarlu Lake from pollution in the Godar River. Dorgeh Sangi is 150 ha in extent and is a shallow freshwater and eutrophic lake. All three lakes may freeze over in winter. Reed cutting, grazing and waterfowl hunting occurs in this complex and some drainage of wetlands for agriculture may occur (Khan *et al*., 1992).



West Azarbayjan, Hasanlou Wetland
(Hassanlou Wetland 2017-02-01 01, CC BY 4.0, Mojtaba Esmaeil Zadeh).

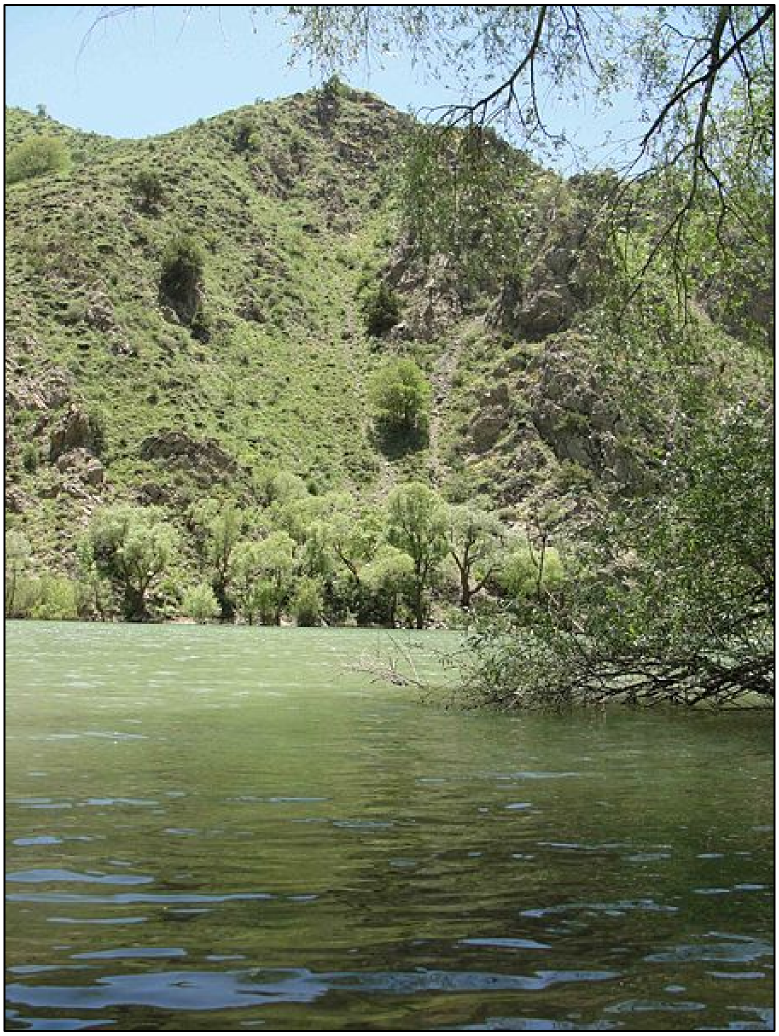
West Azarbayjan, Dorgeh Sangi Lake (CC BY 4.0, cropped, *Tasnim News Agency*).

Gerde Gheet or Gerdeh Git (= Gordeh Git) and Mamiyand at 37°02'N, 45°40'E are freshwater marshes south of Lake Urmia and north of Mahabad occupy 500 ha at 1,300 m. The marshes are covered by *Phragmites*. Waterfowl hunting occurs here and some livestock grazing.

The Ghara Gheshlaq (= Qareh Qeshlaq) freshwater marshes at 37°10'N, 45°50'E occupy 400 ha at 1,290 m south of Lake Urmia and north of Mahabad. The water is about 1 m deep, eutrophic and freezes over in winter. Large parts of these marshes were drained by the Mahabad Multipurpose Drainage and Irrigation Project in the 1970s despite environmental concerns. Cornwallis (1976) noted both the draining of these marshes and the cessation of freshwater discharge from the Mahabad River. He also pointed out the likelihood of chemical contamination from agriculture, choking by vegetation and the probable use of herbicides. He recommended introduction of *Ctenopharyngodon idella* and *Hypophthalmichthys molitrix*. The marshes have been proposed as a Ramsar Site. Lagoons in the Mahabad area dried in the year 2000 (*Islamic Republic News Agency*, 26 July 2000). The Mahabad River is the type locality for *Barbus urmianus*.

West Azarbayjan, Mahabad River, Hamid Reza Esmaeili.

Marmisho Lake lies 45 km west of Urmia and encompasses 5 ha. It is fed by springs and rainfall.



West Azarbayjan, Marmisho Lake
(Marmisho Lake 48, CC BY-SA 3.0, TruthBeethoven).

Guru Gowl, Gori Gol, Gurigöl, Guru, Quri Gol or Lake Gory at 37°55'N, 46°42'E is a fresh to brackish lake near Tabriz occupying 120 ha at 1,950 m. Depth is 2-3 m on average. It is a Ramsar Site (World Conservation Monitoring Centre, 1990; Scott, 1995). The lake is fed by precipitation, by springs and small streams, and overflows through a small stream. The lake freezes over in winter. The submerged vegetation is abundant and there are extensive reedbeds of *Phragmites communis*, *Juncus*, *Carex* and *Scirpus*. It is under pressure from the population of the major city of Tabriz through sport fishing and wildfowl hunting as well as reed cutting and cattle grazing.

East Azarbayjan, Lake Guru Gowl with cows feeding on plants,
15 October 1973, Neil B. Armantrout.

East Azarbayjan, Lake Guro Gowl, 2 April 2018
(Qurighol wetland 1, CC BY-SA 4.0, cropped, Sanam Kheradmand).

Qanats are found in this basin where surface water is saline. About 225 million cu m of water were produced annually by qanats and wells on the northern and eastern coast of the lake (Alamouti, 1966). Dams are found on the Zarrineh River and on the Mahabad River that flows through Mahabad paralleling the Zarrineh. The Mahabad Dam had a fish catch of 130 tons (*sic*) annually and 300,000 fingerlings (species unspecified) were stocked to save the fish reserves from possible extinction (*Islamic Republic News Agency*, 7 January 1999). The Mahabad Dam has a leech fauna (*Codonobdella trunata*, *Parcanthobdella livanowi*, *Baicalobdella torquata*, *Piscicola geometra*) which may affect local fish farms and fish populations elsewhere if fish are transplanted (Abdi, 1999: www.mondialvet99.com, downloaded 31 May 2000).

West Azarbayjan, Mahabad Dam
(Sadd Mahabad (in Farsi), CC BY-SA 3.0, cropped, Auoob Farabi).

The Nowruzlu Dam on the Zarrineh is at 36°55'N, 46°10'E, occupying 1,000 ha at 1,260 m. It is water storage reservoir with heavy input from surrounding farming activities. The Alavian Dam on the Sufi, Sufichay or Sufian River near Maragheh is 80 m high, 935 m long and has a reservoir of 145 million cu m (http://netiran.com/news/IRNA/html/951214IRGG11.html). The Nahand Dam northeast of Tabriz in the Aji Chay basin was inaugurated in 1995 with a capacity of 30 million cu m and a second dam, the Shahid Madani also near Tabriz, was under construction. Other dams include those at Ahar (Sattarkhan Dam in the Caspian Sea basin), Tabriz, Hashtrud, Hasanlu, Mianeh (= Onligh) and Heris which were scheduled to be completed in the period 1995-2000 (*Islamic Republic News Agency*, 2 July 2000).

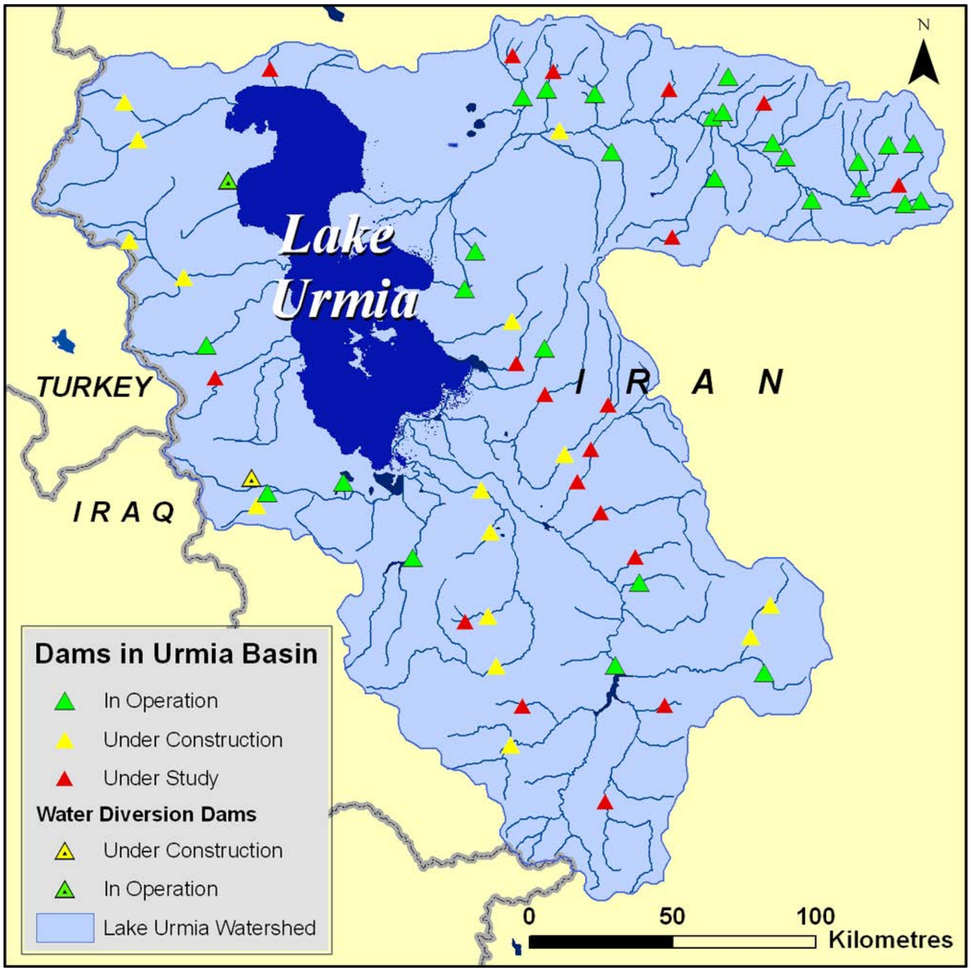
East Azarbayjan, Alavian Dam (cropped, CC BY 3.0, Ayub Farabi Asl).

East Azarbayjan, Sufichay or Sufi River, near Maragheh
(CC BY-SA 3.0, Elmju).

East Azarbayjan, Sufichay or Sufi River, Maragheh
(CC BY 3.0, Ayoub Farabi).

The Hasanlu Dam at Naqadeh was to open in 1998 with a height of 10 m, a crest of 5,160 m (*sic*) and a capacity of 107 million cu m (http://netiran.com/news/IRNA/html/950915IRGG06.html). A total of six reservoir dams and 10 dams for re-directing water flow were expected to decrease water input to the lake by 1.04 billion cu m by 2014. The volume of surface water has fallen from 42 to 22 billion cu m since 1995. The lake salt has increased to more than 260g/l, up from about 185 g/l. The lake was expected to dry up by 2014 (*Islamic Republic News Agency*, 10 September 2001).

Khorasani *et al*. (2004) determined the environmental consequences of the construction of a dam on the Shahr Chay, a river 12 km southwest of Urmia. Recommendations were made as to discharge and it was noted that fisheries potential would increase because of the reservoir.




Dams in Lake Urmia basin
(UNEP GRID, Sioux Falls, South Dakota, 2012).

Löffler (1993) detailed the eutrophication threat to this lake since a traffic embankment or causeway was built across the lake 35 km north of Urmia in 1990. Untreated sewage from Urmia was expected to pollute the southern part of the lake.


Lake Urmia causeway (CC0, light adjusted, ISS052-E-8381 - View of Iran, NASA).

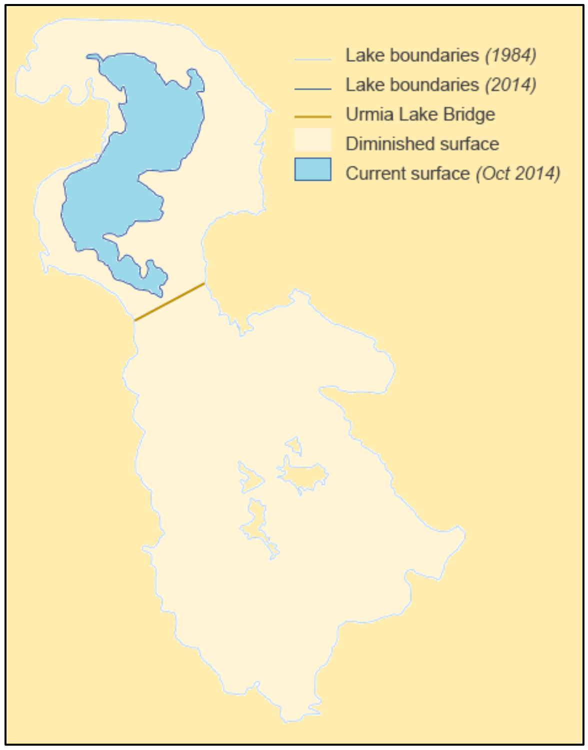
Pollution occurs in various localities on a sporadic basis such as the Gadar (= Qader) River in Naqadeh where a fish kill numbering in the thousands was reported (*Tehran Times*, 18 July 1999). Haji Hassani *et al*. (2004) found that levels of copper, lead and nickel in the Talkheh (= Aji) River were higher than acceptable limits for fish culture while chromium and iron were lower. The river receives wastewater from agricultural and industrial activities. Honarpajouh (2003) studied pesticide residues in the Mahabad and Simineh rivers and Tarahi Tabriz (2001) studied three pesticide residues in the Nahand River. Fathi and Ahmadifard (2019, 2020) studied the effect of wastewater on the fish community and water quality in the Saqqez River (a Zarrineh River tributary). The city of Saqqez has increased the amounts of nitrate and phosphate in the river causing the removal of some fish species and the presence of herbivorous species. *Capoeta gracilis* (= *C. capoeta*) showed the highest abundance of all four stations sampled. The frequency of *Carassius auratus* showed the highest correlation with nitrate, phosphate, ammonium and biological oxygen demand. Biological oxygen demand and ammonia values in the effluent stations were higher than the threshold for growth of warmwater fish.

Morid (2012), Khalyani *et al*. (2014), Merufinia *et al*. (2014), Shariatmadari *et al*. (2015), Stone (2015) and Alizade Govarchin Ghale *et al*. (2018) gave details of the degradation or loss of water in Lake Urmia. There is now an extensive literature available online about Lake Urmia and its problems although, as the salt lake did not support a fish fauna, the relevance to fishes is indirect. AghaKouchak *et al*. (2014) referred to this loss of 88% of the water as the Aral Sea syndrome. Ironically, the name “Urmia” is Assyrian for “puddle of water”. Drought, coupled with dam construction, the Shahid Kalantari Causeway cutting the lake in half, abstraction of water for irrigation, and an estimated 40,000 illegal wells reducing groundwater recharge to rivers, have led to this desiccation. Mirchi *et al*. (2015) pointed out that desiccation leads to salt storms that destroy agricultural land and presumably has serious effects on freshwater habitats. Alizade Govarchin Ghale *et al*. (2018) found that anthropogenic impacts accounted for roughly 80% and climate factors roughly 20%, of effects on the drying up of the lake.

Proposed water transfers to resolve desiccation bring more ecological problems as

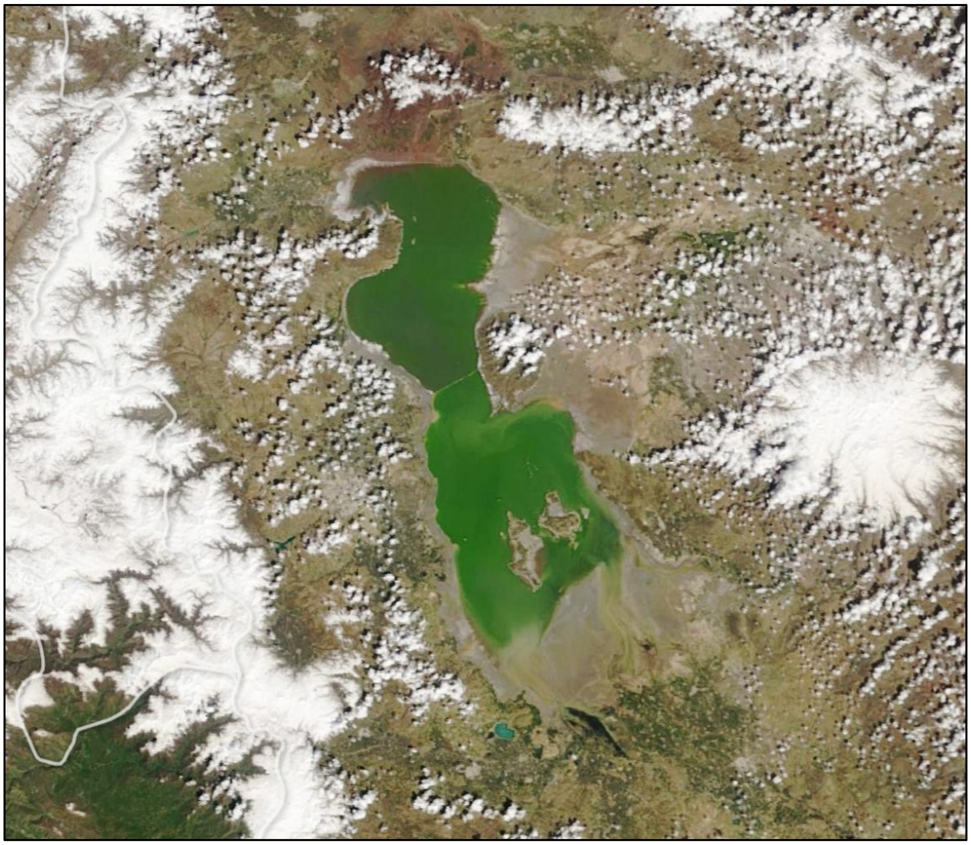
detailed elsewhere in this work. The Silveh Dam on the Lavin River in the Little Zab River basin (Tigris River drainage) was scheduled for completion in 2015. A tunnel and canals will transfer up to 121,700,000 cu m of water to the Lake Urmia basin annually. The *Financial Tribune* (2 October 2015) mentioned plans to transfer water by 2019. There was also a proposed diversion from the Aras River, voted against in August 2011 by the Iranian parliament. Agh *et al*. (2015) gave a PowerPoint Presentation of proposed major diversions of rivers in order to rescue the drying lake. Water at 40 cu m/sec was released from the Mahabad Dam in 2016 to help restore the waters of Lake Urmia. In addition to water from the Mahabad Dam, the Simineh and Zarrineh rivers have also been connected to Lake Urmia. The Boukan Dam releases into these rivers, allowing for an annual transfer of 200 million cu m of water into the lake. The Aji Chay has also been channelled to Lake Urmia to contribute to the lake's replenishment.

Lake Urmia, 23 June 2014, at 5% of high stage volume
(green and tan is water, white is salt deposits)
(CC0, NASA).



Lake Urmia shrinkage
(CC BY-SA 4.0, Atila Kagan).

Torrential rains in 2019 replenished the water, expanding the extent nearly two-fold from a year ago.



Lake Urmia, 12 April 2019, ca. 3,000 sq km
(CC0, cropped, NASA Earth Observatory).

Water reservoirs behind the Mahabad, Miandoab and Shahid Kazemi dams were stocked with 3.6 million fish fry (species not specified) from the Pol-e Dasht Complex in 2000. This aquaculture site has the capacity to produce 4 million fry. West Azarbayjan produces over 600 tons of fish annually (*Tehran Times*, 2 January 2001). In the Iranian year ending 20 March 2002, 840 tonnes of coldwater fish were produced and 3,000 t of warmwater fish (*Tehran Times*, 24 November 2002).

Lake Urmia is the largest natural habitat for brine shrimp in the world and, since 2000, shrimp have been harvested, processed and used to feed principally sturgeon in hatcheries (www.worldfishingcompanies.com/html/us/world.report.html?id=1, downloaded 23 October 2001). Brine shrimp have also been used elsewhere in warmwater (e.g., *Cyprinus carpio*) farming.

Günther (1899) detailed a method of catching fish used in the rivers of this basin. Flour and the pounded berries of *Cocculus indicus* (= *Anamirta cocculus*, Indian berry or fishberry) were mixed with butter to form a stiff paste. Small pellets of the paste were thrown into slow flowing water and after 10-15 minutes, if the fish were feeding, they would begin to swim at the surface in small circles or lie helpless in the shallows and were then easily scooped up. Some fish could recover from the poison. There was no effect on humans if poisoned fish were eaten.

The lake was formed during the late Pliocene-Pleistocene and lies at 1,275-1,300 m and may well have had a Pleistocene connection to the Caspian Sea basin although this is in dispute (Scharlu, 1968; Schweizer, 1975). Pleistocene shorelines from 30 to 115 m above the present level have been confirmed, and the lake covered twice its present area, but this would not permit

an external discharge. Berg (1940) reported benches at levels of about 1,800 m, 1,650-1,550 m and 1,500-1,360 m, which may represent shorelines, and a level of about 1,570 m would have had an outlet to the Aras River basin through the Kara-tepe Pass in the northwest and across the plain near Khvoy. Saadati (1977) suggested two connections with the Caspian Sea, an early one in the Pliocene to early Pleistocene resulting in endemic species and a later one in the late Pleistocene resulting in species which are the same as the Caspian or only subspecifically distinct. Stream capture may have allowed the entry of some species in recent times as evidenced by a *Salmo cf. trutta/caspius* population. The palaeogeography of the Late Miocene of this area was given by Reichenbacher *et al*. (2011) and fossil fishes included the cyprinids *Leuciscus* sp. and *Scardinius* sp., the atherinid *Atherina atropatiensis* and the aphaniid *Aphanius persicus*. An ancient euryhaline Lake Urmia was located further to the east of the present-day Lake Urmia and probably had temporary connections via an ancient Aras River passage to the Caspian Sea.

Berg (1940) considered that this basin falls within his assignment of the Iranian shore of the Caspian Sea. Species in common included *Leuciscus cephalus* (= *Squalius turcicus*), *Barbus lacerta* (= *B. cyri*), *Gobio* (= *Romanogobio*) *persus* (now an endemic, see Coad (2019b)), *Capoeta capoeta, Alburnoides bipunctatus* (= the endemic *A. petrubanarescui*) and *Silurus glanis* (European catfish), and in addition *Acanthalburnus* (= *Acanthobrama*) *urmianus* is related to *A. microlepis*. Groombridge (1992) noted that the ichthyofauna of this region was badly in need of re-examination and recent studies have clarified knowledge of the fauna. Naseka (2010) recognised Lake Urmia as a District within a West Asian Transitional Region related zoogeographically to the East Transcaucasian District (southern Caspian Sea area from the Kura River to the Atrak River). Both these Districts are linked to Iranian endorheic basins, including those listed as ecoregions in Abell *et al*. (2008), namely Namak, Kavir, Lut, Esfahan and Sistan, plus Kor, Sirjan, Maharlu Kerman-Na'in and Jaz Murian basins in this work.

The ichthyofauna of part of this basin in northwestern Azarbayjan was reviewed by Yahyazadeh *et al*. (2007, 2015). The record of *Leuciscus idus* (Linnaeus, 1758) in Yahyazadeh *et al*. (2015) from the Godar River of this basin needs confirmation of this exotic for Iran.

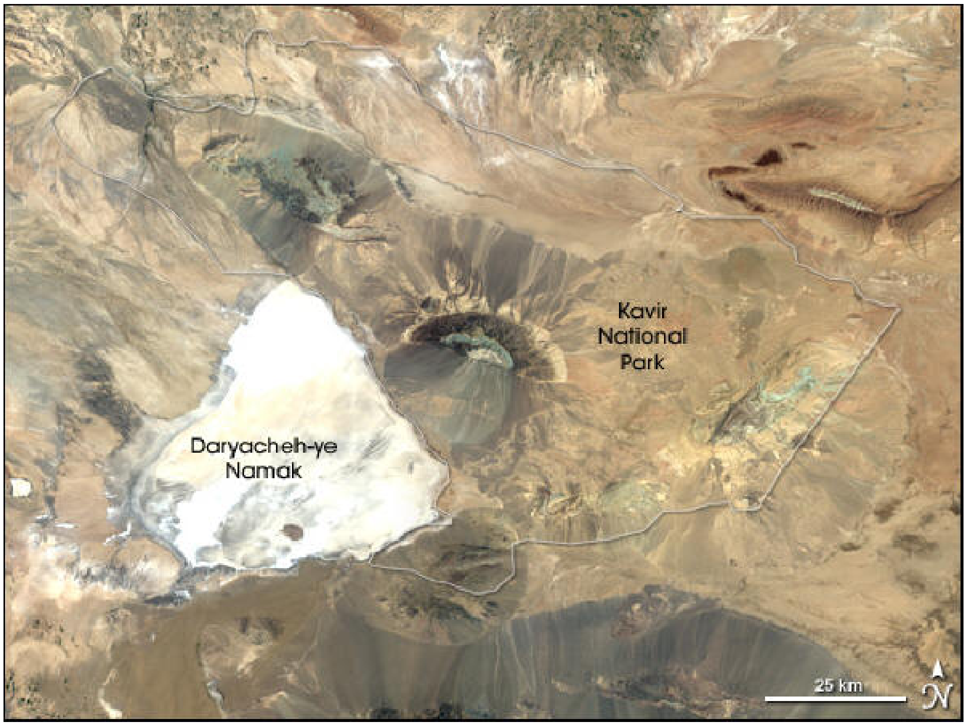
Afham and Falsafian (2017) analysed and identified the price and non-price factors affecting willingness to consume fish among 220 households of Urmia City in 2016. Results showed that 20% people were not willing to consume fish, and only 19% had a high tendency to consume fish. A living location close to a fish shopping mall, existence of elderly people in the household and children under ten years old had a significant impact on increasing willingness to consume fish, and also the existence people with a specific disease in the household and the price of fish decreased the tendency to consume fish. Awareness of the benefits of fish consumption and general conditions of purchase (including price, taste, packaging, easy access to shopping centres and freshness) were not adequate and effective planning and efficient advertising were recommended.

## Namak Lake

This basin is flanked by the Alborz Mountains to the north and the Zagros Mountains to the west. On the east is the vast expanse of the Dasht-e Kavir basin and on the south such ranges as the Kuh-e Karkas at 3,899 m (33°27'N, 51°48'E).

Namak Lake basin
(IranCatchCen1, CC BY-SA 4.0, Mahdy Saffar).

The basin encloses about 87,600 sq km (92,000 sq km in the Encyclopædia Iranica, www.iranicaonline.org/, downloaded 10 July 2016). The Namak Lake is saline and fishless but tributary rivers and streams house an ichthyofauna. The basin is the type locality for *Alburnoides namaki*, *Barbus miliaris*, *Capoeta aculeata* (probably), *Capoeta buhsei*, *Squalius namak*, and see also below under the Karaj, Nam and Qareh Su rivers. The lowest part of this basin is at 765 m and is covered by water in spring but this generally evaporates by the middle of summer leaving salt crusts.



Namak Lake
(CC0, NASA).

A small sump near Arak (34°05'N, 49°41'E) is included as part of this basin as it is not separated by any major landform. A second salt lake is the Howz-e Soltan by the Tehran-Qom road and this lies in the same depression as the much larger Namak Lake south of Tehran.

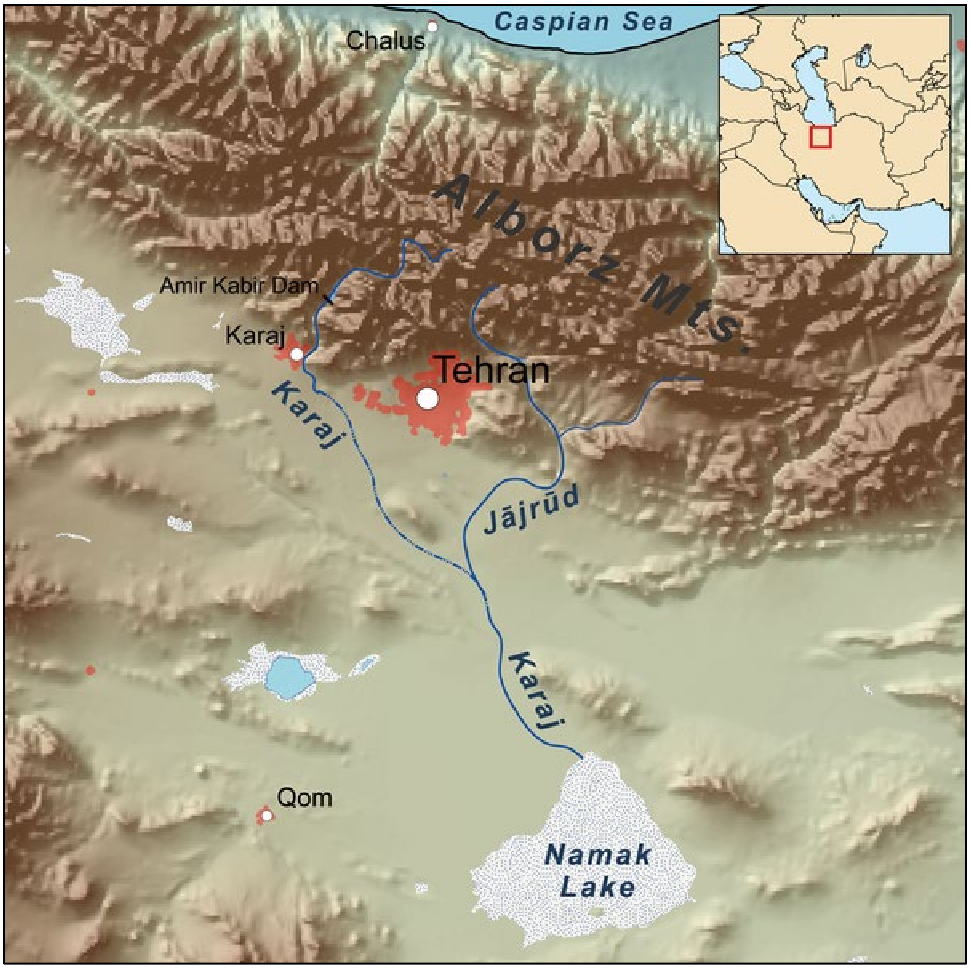
Qom, Howz-e Soltan
(CC0, NASA).

Qom, Howz-e Soltan
(Soltan salt lake, CC BY-SA 4.0, Amirpashaei).

The proximity of the capital, Tehran, to the rivers of this basin and its rapid growth in population and industry has led to many water diversionary schemes (Anonymous, 2003). A proposed dam northwest of Tehran would be the largest man-made lake in the country and the Middle East (*sic*) (Nouri *et al*., 2005). Much of this basin lies in the former Markazi or Central Province which has 42 dams of varying sizes. The Abbasabad Embankment Dam in Khomein, for example, is 36 m high, has a crest of 260 m and has a reservoir of 25,000 ha (*Islamic Republic News Agency*, 3 February 1999). The Mamlu Dam collects portions of the Jaj River and Damavand basins as well as managing torrent and flood waters to irrigate 64,000 ha of Varamin's agricultural lands plus supplying part of Tehran's drinking water. Mamlu is an embankment dam 89 m tall with an arch spread 807 s long. It holds 24% more water than the Karaj Dam, one of Tehran's main water sources, and was to be operational by September 2007.

Tehran, Mamlu Dam and Mount Damavand
(SadMamlooAndDamavand, cropped, CC0 1.0, Wurzelgnohm).

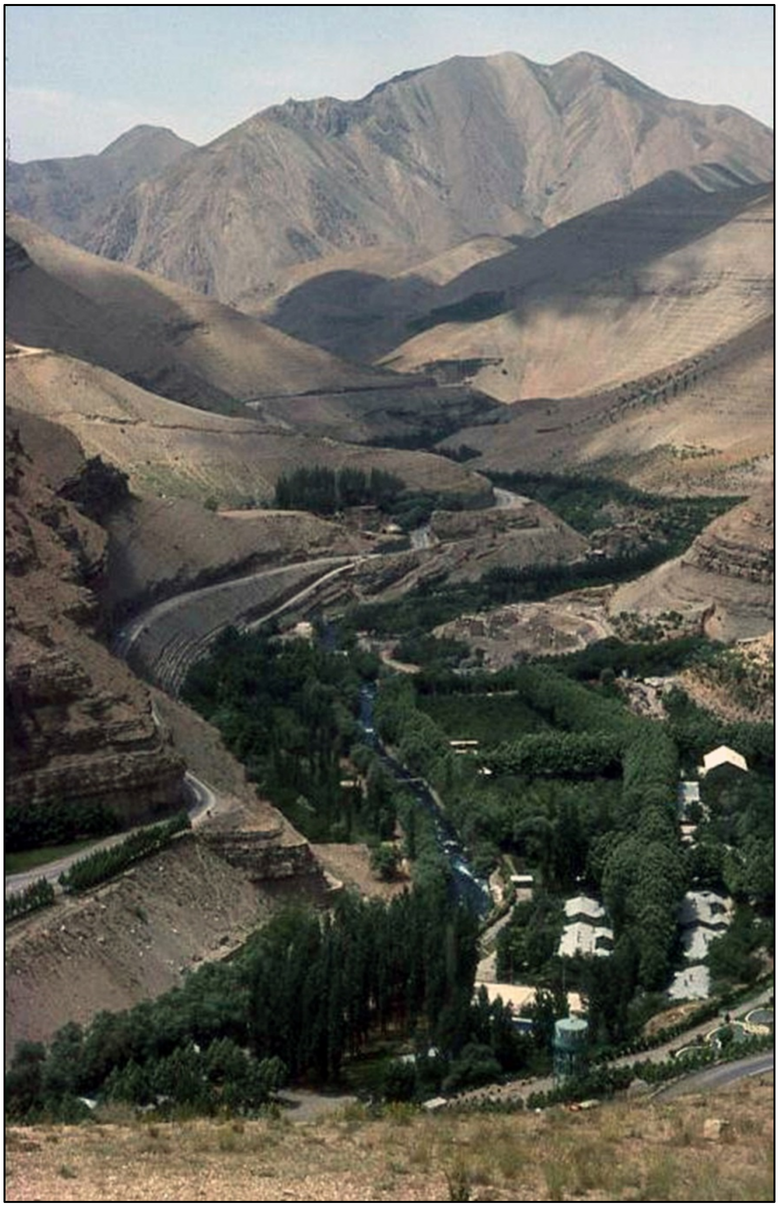
The principal river in the west draining the Alborz south towards the Namak Lake is the 245 km long Karaj River with an average annual discharge of 499 mcm. This river is the type locality for *Barbus kessleri* (= *B. miliaris*), *Varicorhinus bergi* (= *Capoeta aculeata*) and *Varicorhinus nikolskii* (= *Capoeta buhsei*).



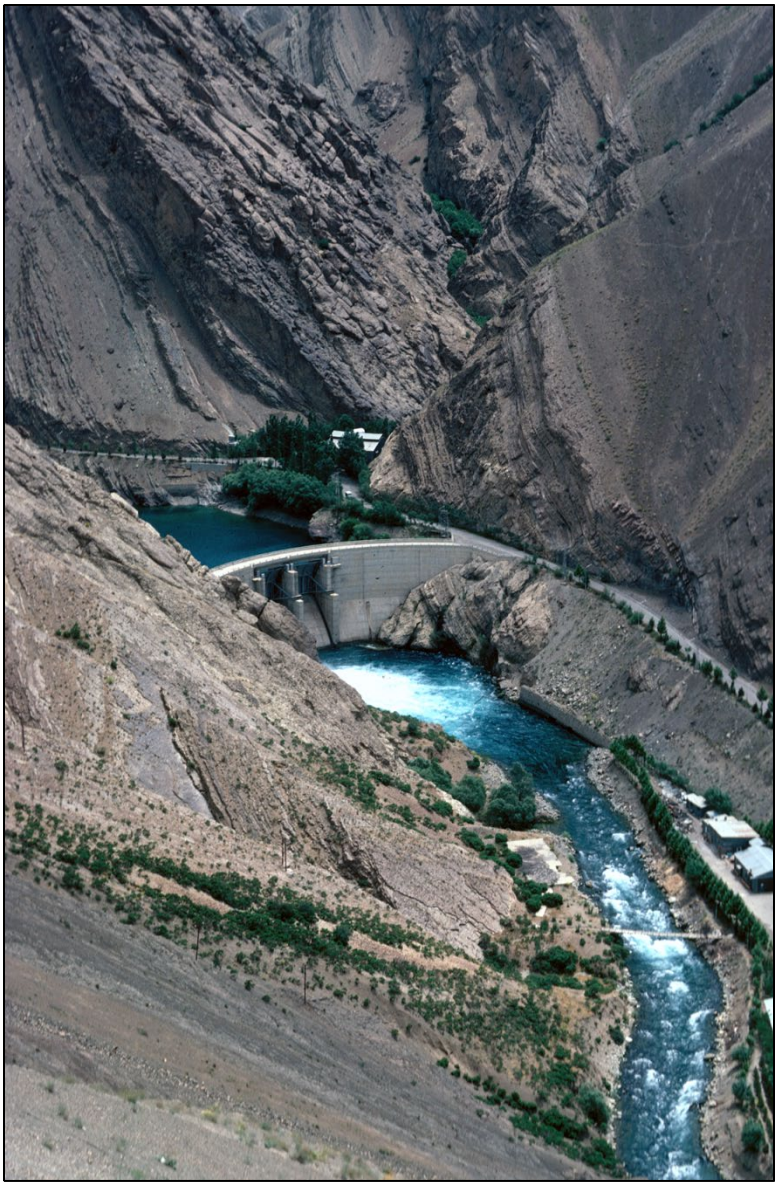

Karaj River basin
(Karaj river map, CC BY-SA 3.0, Kmusser).

Average temperatures of the Karaj River at the dam site before construction ranged from 2.5°C in January to 16.4°C in August (Nümann, 1966). Rieben (1954) and Hariri (1966) gave details of surface and ground water in this river basin. Sakizadeh *et al*. (2015) assessed water quality in the river and found it to be between permissible and slightly polluted. Ranges for variables were pH 7.8-8.58, chemical oxygen demand 3.0-6.0 mg/l, conductivity 226-368 µS/cm, total dissolved solids 90-148 mg/l, nitrite 0.0-0.02 mg/l, nitrate 0.18-0.79 mg/l, sulphate 30-50 mg/l, total coliform 23-1,300 n/100 cc (presumably n = most probable number) and faecal coliform 4-1,300 n/100 cc. The Amir Kabir or Karaj Dam on the Karaj opened in 1961, has a height of 180 m and contains 205 million cu m of water and feeds through pipelines to Tehran. The reservoir has an area of 4 sq km at high water, 1.1 sq km at low water. Vladykov (1964) and Nümann (1966, 1969) gave some details on the limnology of this reservoir, particularly temperature regimes. The Karaj has a discharge of 124 cu m per second in spring but this falls to 4.2 cu m per second in autumn. 55.6% of the annual discharge occurs during spring. There is no vegetation because of

the steep rock sides and water fluctuations. Nümann (1966) recommended stocking the Karaj Dam with the salmonid *Coregonus* sp., *Sander lucioperca* (pike-perch), *Acanthobrama terraesanctae* (a Levantine species) and cichlids from Israel as environmental conditions and plankton levels were suitable. Nadim (1977) found the highest mercury levels in fish from the Karaj were 0.05 mg/kg. As the acceptable limit was 0.5 mg/kg, mercury contamination in fish was not considered a problem. Musavi and Pourebrahim (2019) assessed water quality using benthic macroinvertebrates and found river water had a moderate pollution based on the Shannon index and a suitable quality according to the Hilsenhof index in the upper stations (Sierra and Polekhab) and had less quality at the lower stations (Aderan and Pourkan). Ghalandarzadeh *et al*. (2020) demonstrated that in both water and sediment samples, there were significant concentration of the heavy metals cadmium, chromium and zinc from upstream to downstream stations. The concentrations of all metals in water and sediment were lower in January than in July. The results of the Z biological value index revealed significant differences in both seasons between the sampling stations, and the highest values were recorded in downstream stations in both seasons. Contamination of heavy metals, especially downstream, was due to human interventions such as agricultural, urban and industrial activities and production of wastewaters. In the cold season, because of reduction in population density in the vicinity of the river area, pollution levels decreased. In general, in terms of water quality index, the Karaj River was classified in the saprobe class between II and III.



Alborz, Karaj Valley, 4 June 1978, Brian W. Coad.


Alborz, Karaj or Amir Kabir Dam, 4 June 1978, Brian W. Coad.

Alborz, Karaj or Amir Kabir Dam
(Karaj dam 1, CC BY-SA 4.0, H. Abri).

Alborz, Karaj River
(Karaj river 2573227920, CC BY 2.0, Ninara).

The Kordan River northwest of Karaj is about 48 km long and drains 1,100 sq km. Mousavi Nadushan and Ramezani (2011) assessed water quality using macro-zoobenthos indices and rated it fair to good and some to fairly substantial pollution at differing sites. They found mean water velocity was 116 cm/sec, water depth rarely exceeded 75 cm, water temperature range was 4.0-18.7°C, dissolved oxygen was 9.3-11.9 mg/l, biological oxygen demand was low at all times at all sites, conductivity was 256-417 μS/cm, nitrate was 0.26-0.56 mg/l and phosphate 0.011-0.027 mg/l. Nitrate increased downstream from agricultural fertilisers and urban sewage. Morid *et al*. (2016) assessed climate change impacts on river hydrology and habitat suitability of a nemacheilid *Oxynoemacheilus bergianus* and predicted a reduction in discharge

and changes in occurrence time of maximum and minimum flow. Habitat suitability will change and introduce some risks for aquatic life, including fishes.

Alborz, Kordan River, Arash Jouladeh-Roudbar.

The Abhar River and its tributaries drain the land west of Tehran and south of Qazvin (36°16'N, 50°00'E). Its headwaters approach those of the Zanjan River, a Caspian Sea tributary. The course of the Abhar is about 350 km from its headwaters to the terminal sump. The lower part of this river is known as the Shur and is salty. Sewage and untreated factory wastes, as much as 40,000 cu m, flowed into the streams around the city of Qazvin although wastewater and sewage treatment plants are offsetting this problem (http://netiran.com/news/IRNA/html/941220IRGG05.html). The hydrogeology and

hydrogeochemistry of the Abhar Plain were studied by Jalili *et al*. (2014) and the aquifer is endangered by overdraft and a negative water budget.

Other rivers draining the Alborz are much shorter. The Jajrud (Jajrood, Jaj, Jaji or Jaje River) to the east of Tehran is dammed at Latian (opened 1967, 107 m high, capacity 95 million cu m) for the Tehran water supply also. It is tributary to the Karaj River. The Jaj River discharge is 60.5 cu m per second in spring and 1.5 cu m per second in autumn. Nümann (1966) reported fish kills in the thousands for *Capoeta buhsei* on turbid spring floods of this river. Khorasani (2001) gave an environmental survey of this river. Mirzaei *et al*. (2010) gave details of Eurasian Otters feeding on *Alburnoides bipunctatus* (= *A. namaki*), *Squalius cephalus* (= *S. namak*) and *Capoeta* spp. in the Jaj River. Parvandi *et al*. (2016) assessed the water quality in the Jaj River using macrobenthos community structure and found it unsuitable in 10 out of 12 stations. Khezri *et al*. (2019) used both fish and macroinvertebrate indices with physicochemical parameters for an ecological integrity assessment of the Jaj River, finding the urban-rural and agriculture wastewaters and the Latian Dam had the most negative impacts on the ecological structure of the river. Ameri Siahouei *et al*. (2020) surveyed the water quality and riparian zone of the Jaj River noting major increases in exploitation of the riparian zone over 10 years (270.45% for issuance of building permits, for example) and biological oxygen demand, total dissolved solids and ammonium of the water exceeded allowable limits by 14, 16 and 17 times respectively. A 168 ha area of the riparian zone needed to be rehabilitated to reduce and control non-point source water pollution. Mehrjo *et al*. (2020) used benthic macroinvertebrates to find water quality at five downstream locations was not good. The Band Ali Khan River flows from the Khasrang Mountain (as does the Jaj River which it receives) and its branches on the Varamin Plain are used for irrigation. Much of this river is polluted from wastes in the Jaj River and Tehran's sewage floodway (Rohani, 2004; Kashefi Alasl and Zaeimdar, 2009). Mirzaei and Hasanian (2013) sampled 10 stations for nine years on this river and found water quality classified as medium, better in the wet season compared to the dry season and the river has a good attenuation capacity.

Tehran, Jajrud or Jaj River at Shah Abbas Bridge
(Jajrood Bridge, CC BY-SA 4.0, Manfi).

Tehran, Tehran with Jaj River and Latian Dam at upper right and Karaj River at left (CC0, NASA).

The Lar River, a Caspian Sea tributary, was scheduled for diversion via a massive tunnel into the Jaj River (Marwick and Germond, 1975a, 1975b). This would affect flow in the Haraz River of the Caspian Sea basin and plans to offset this involved weirs and canal construction no doubt with the usual deleterious effects on fishes. These major projects are a far cry from the days in the twentieth century when Tehran depended solely on qanats for its water supply (Rieben, 1954).

Tehran, Lar River near Kharsang
(CC BY 3.0, Mahdi Kalhor).

The river is dammed by the Lar Dam 84 km northeast of Tehran and is used for the Tehran water supply. Salavatian *et al*. (2012) described the food chains in the reservoir, 95% of the fish caught being *Salmo trutta fario* (presumably *S. caspius*). Rainbow trout, *Oncorhynchus mykiss*, were also present. This reservoir has low potential for planktonic productivity and due to its geographical location, remarkable temperature differences can be observed in different years, especially in fall and winter. Construction of the Lar Dam increased sediment load in the Haraz River downstream with subsequent effects on benthic fish feeding there (Gholami *et al*., 2013).

Mazandaran, Lar Dam and Mount Damavand
(Damavand & Lar Dam …., CC BY 3.0, Mahdi Kalhor).

Mazandaran, Lar Dam
(Lar Lake, CC BY 3.0, Alireza Javaheri).

The Namak Lake receives the Qareh Su (or Gharechay) which flows north of Qom, and the Qom River from the Zagros Mountains. Discharge of both these rivers is about 312 cu m per second in flood falling to about 4 cu m per second in October (Oberlander, 1968b). The Qareh Su exceeds 400 km in length. The Qom River has captured headwater streams of Persian Gulf drainage. The Qareh Su is the type locality for *Alburnus amirkabiri* (= *A. doriae*).

Qom, Qom River at Qom, Flandin (1840).

Qom, Qom River at Qom, 3 May 2007
(Mosalla va Rodkhaneh …., CC BY-SA 4.0, Mostafameraji).

Qom, Qom River in Qom
(Iran - Qom metropolis - Qom province …., in Farsi, CC BY 4.0, Mostafameraji).

Qom, Qom River in Qom
(Rodkhaneh …., in Farsi, CC BY-SA 4.0, cropped, Mostafameraji).

The Golpayegan River near Golpayegan has a storage reservoir, the Shah Esma`il Dam. Borowicka (1958) gave some early figures on siltation and irrigation requirements. The Haroon Canal had diverted water for irrigation from the Golpayegan River for over 1,000 years, and during the summer and fall all river water entered this canal. The Ghadir or Qadir Dam near Saveh has a volume of 290 million cu m of water. The 15th Khordad Dam is located 80 km south of Qom on the Qom-Delijan road (http://netiran.com/news/IranNews/html/95030718INPL.html). The Khandab Diversionary Dam is near Arak (http://netiran.com/news/IRNA/html/951217IRGG09.html).

Egglishaw (1980) gave some details on the water quality and environment of rivers and streams of this basin. Imandel *et al*. (1978) recorded ground water pollution by detergents in Tehran, where there was then no method of sewage disposal other than discharge to wells and seepage pits. Södergren *et al*. (1978) reported on pollution with organochlorines in the Karaj and Latian dams. *Capoeta buhsei*, *Alburnoides bipunctatus* (= *A. namaki*) and the salmonids *Coregonus* sp. and *Oncorhynchus mykiss* (rainbow trout), had accumulated the DDT metabolite *p,p*′-DDE, particularly in the Latian Dam. Direct removal of plants for fuel and laying bare the roots of such thorny plants as giavan for extracting gum tragacanth leading to plant loss caused soil loss by erosion, gullying and affected recharge of groundwater. Poor farming practices on steep slopes had also led to the loss of topsoil such that runoff was too fast for infiltration of rain and snow (Rieben, 1954). These factors caused silting of reservoirs, added silt input to rivers and reduced groundwater recharge with consequent reduction in spring and qanat flows, all detrimental to fish habitats. Some areas of southern Tehran received 300 kg/ha/yr of sulphate ions as acid rain which lowered river pH and had effects on the fish fauna (Salahi Kojoure, 1997). An effluent leak from a power station in the Vian area of Hamadan sent 40-50,000 litres of furnace oil into 1 km of river in the Qareh Su basin (*Iran Network 1*, Persian TV, 1730 GMT, 2 January 2000). Monavari and Mardani (2007) recorded the effects of sewage from fish culture ponds in this basin on water quality in the Jaj River, most factors being within acceptable limits except coliform bacteria. Kloosterman (2014) reported on an estimated two million fish or 30 tons being killed in the Fashafuyeh Dam, south of Tehran, as a result of a raw human sewage discharge. Ahani (2011) found water quality below the Latian Dam on the Jaj River was

generally average and the presence of pollution-tolerant benthic organisms indicated that the environment was ecologically unhealthy.

Drinking water is diverted from the Dez River in the west (Tigris River basin) to the city of Qom. The necessity for this is brought out by the ranking of the Qom River as the most water-stressed in the world (www.wri.org/blog/2014/03/world%E2%80%99s-18-most-water-stressed-rivers).

Qanats are still a major feature of this basin. Alamouti (1966) recorded 260 qanats producing 99 million cu m per year on the Varamin Plain (35°20'N, 51°39'E), 220 qanats producing 161 million cu m per year on the Karaj Plain and 600 qanats producing 200 million cu m per year on the Qazvin Plain. Numerous pump wells have led to the drying of qanats and a complex irrigation system has reduced groundwater recharge (Beaumont, 1974). Alibekov (1994) gave a Russian account of qanats in Central Asia and also referred to those around Tehran in the Namak basin. Alizadeh Sabet (2017a) carried out a feasibility study of water resources from the Salehabad Qanat for fish production.

Chitgar or Persian Gulf Martyrs Lake is an artificial water body of 130 ha in northwest Tehran in the Namak Lake basin which has a complex fish fauna including a number of introduced tropical exotics as well as cyprinoid species native to Iran. Exotics were listed as belonging to the families Cichlidae, Loricariidae, Pangasiidae, Poeciliidae, Salmonidae, Scaridae and Serrasalmidae (Ramin *et al*., 2017, 2018). Bagheri *et al*. (2017) carried out an ecological study of zooplankton communities in this lake and concluded it was meso-oligotrophic and could trend to eutrophic without appropriate management. Abedini *et al*. (2017, 2018) gave details of water quality and the lake was ultra-oligotrophic. Introduced cyprinoids included *Alburnus hohenackeri* (35% frequency by seine net and 38% by cast net), *Carassius auratus* and *Carassius gibelio*, *Cyprinus carpio*, *Hemiculter leucisculus* and *Pseudorasbora parva*. The only native cyprinoid was *Capoeta buhsei*. Abedini *et al*. (2022) found the lake was ultraoligotrophic in its early years after filling from the Kan River in 2012 and during 2016-2017 the eutrophication state was close to mesotrophic and then it almost returned to its original level during the downward trend after the summer of 2018. Introduced fishes and refinery performance were the two main factors that contributed to the declining level of eutrophication in the lake.

Tehran, Chitgar Lake in Tehran
(Aerial photographs of District 22 Tehran …., CC BY 4.0, Mohsen Ataei).

The Qazvin area had more than 20 aquarium fish farms producing over two million fish (Tehran Times, downloaded 28 July 2004). Waters in this area drain also to the Caspian Sea and there may be potential for escapes of exotics. Artificial lakes used for fish farming in Shemiranat district in northern Tehran depended on groundwater sources which Farahmand (2015) found to be polluted in varying degrees by arsenic, cadmium and iron.

Adeli *et al*. (2020) evaluated marketing at the Tehran big fish market where customers prefeered to buy salmon and Persian Gulf and Sea of Oman fish, shrimp, warmwater farmed fish (cyprinoids) and Caspian Sea fish (including some cyprinoids).

Berg (1940) referred this basin to his Tehran District of the Iranian Province. He noted that some drainages are close to those of the Caspian Sea basin and that the fauna may be of quite recent origin, rather than the Pliocene advocated by Derzhavin (1934) for *Salmo trutta* (or presumably now *S. caspius*, Caspian trout). Saadati (1977) considered that the fish fauna of this basin was not derived from movements through a large freshwater lake connecting all the tributaries. Some species came from the Caspian Sea basin and others from the Esfahan and Tigris River basins. The basin may also have served as a filter-bridge allowing such species as *Capoeta aculeata*, *Capoeta capoeta* (*sic*) and the progenitor of *Capoeta fusca* to reach the Dasht-e Kavir basin.

Sirjan

The Sirjan basin extends south-east of the Esfahan basin and parallels the Kerman-Na'in basin. It is named for the town of Sirjan at 29°28'N, 55°42'E which lies at the edge of the largest salt flat in the basin. It is somewhat higher than the Esfahan basin which is at 1,300 m, being 1,448-1,710 m. It is distinguished from the Esfahan basin by its lack of a significant river. There are four major sumps in this basin, strung out along its length at regular intervals, and the northern two are connected as are the southern two. The sumps are fed by intermittent streams. Qanats and minor springs are found in this basin which has not been extensively explored. The sump in the north near Abarqu (31°08'N, 53°17'E) receives streams from the west (Kuh-e Bul at

3,661 m and 30°48'N, 52°45'E) and from the east (Khar Kuh at 3,512 m and 31°39'N, 53°46'E, and Shir Kuh at 4,074 m and 31°37'N, 54°04'E). The southern basins near Sirjan receive their streams from lower elevations.

Sirjan basin
(IranCatchCen7, CC BY-SA 4.0, Mahdy Saffar).

Tedesco *et al*. (2013) listed this basin as one of 20 basins out of 1,010 studied likely to suffer the greatest biodiversity loss due to water availability shrinkage from climate change.

Sistan

The Sistan (= Seistan) basin straddles the Iran-Afghanistan border and is a north-west to south-east oval in shape. It is the type locality of *Discognathus adiscus* (= *Tariqilabeo adiscus*), *Discognathus phryne* (= *Garra nudiventris*), *Discognathus rossicus* var. *nudiventris* (= *Garra nudiventris*), *Scaphiodon macmahoni* (= *C. watsoni*), *Schizocypris altidorsalis* and *Aspiostoma zarudnyi* (= *Schizothorax zarudnyi*). The basin comprises a number of minor streams and qanats flowing from the west and the Birjand highlands, but these are rapidly absorbed or run for only a few days each year. Its most obvious feature is the vast *hamun* or swamp comprising open freshwater lakes, reed beds or *neizar* (*Phragmites communis*) and rushes (*Typha angustifolia*) standing 3-5 m high, and the rivers that feed the lakes. This is a major oasis of fresh water surrounded by hundreds of kilometres of arid plains. Huntington (1905a, 1905b), Annandale (1919a), Dominguez *et al*. (1951), Ahmadi and Wossughi (1988), Noorbakhsh (1993), Mansoori (1994), Ibrahimzadeh (1995), Scott (1995), Weier (2002), CIRSPE (2006a), Vekerdy and Dost

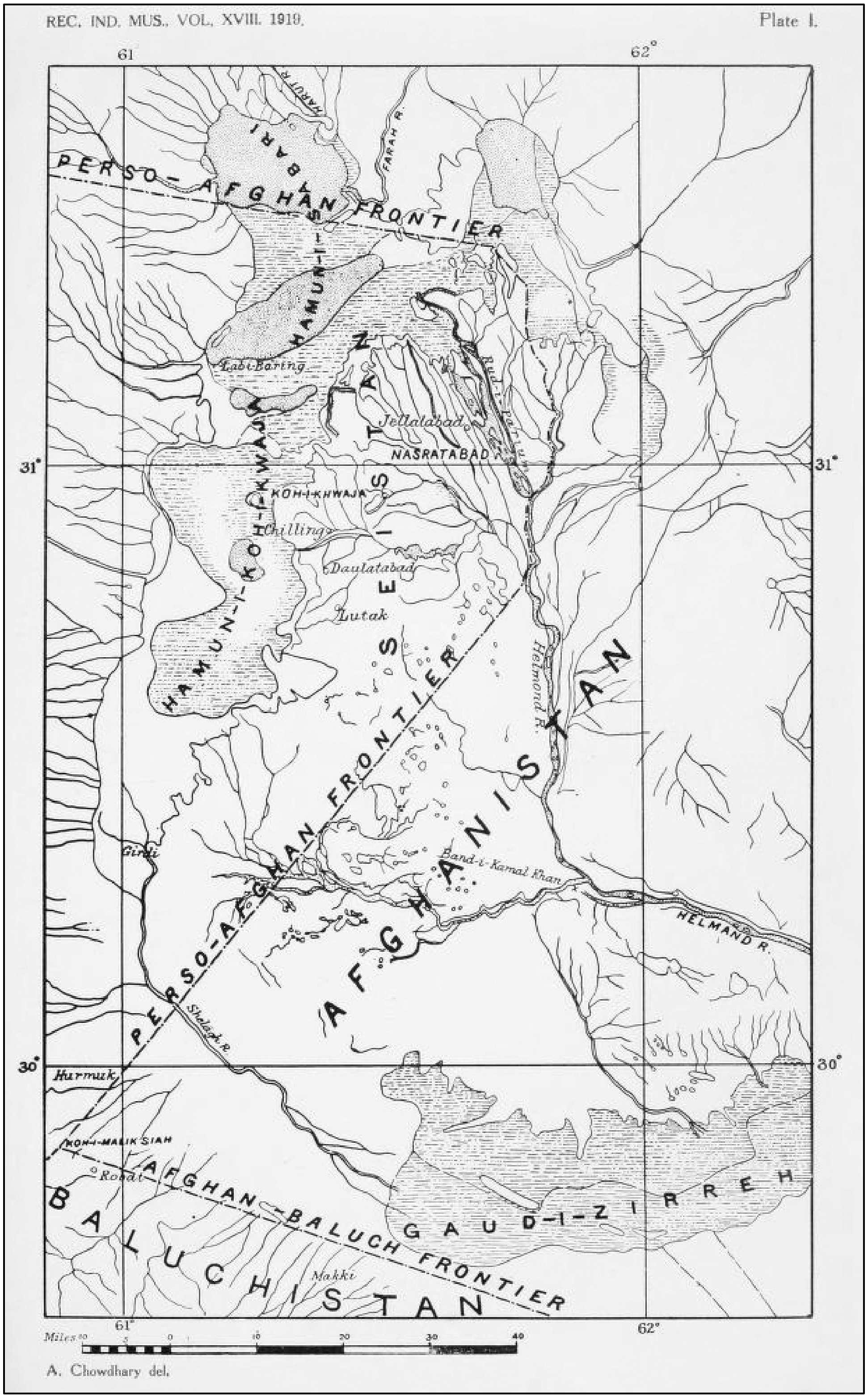
(2006), Whitney (2006), van Beek *et al*. (2008), Dahmardeh *et al*. (2009), Najafi and Vatanfada (2011), Piri (2011), Rashki *et al*. (2012), Sharifikia (2013) and Dudgeon (2020) gave descriptions of this basin and its environmental challenges. Note that Weier's (2002) statement (repeated in various newspaper reports and in UNEP (2003)) that there are nearly 140 species of fish in Sistan is an error by an order of magnitude! The native ichthyofauna comprises a mixture of endemic species, species related to or conspecific with high-altitude species from Central Asia and species from Baluchestan in the wider sense. There is little relationship to species from Iran to the west. Variations in water level and crowded conditions lead to disease and parasite outbreaks in the fishes (Mansoori, 1994).

Sistan basin
(IranCatchEast2, CC BY-SA 4.0, Mahdy Saffar).

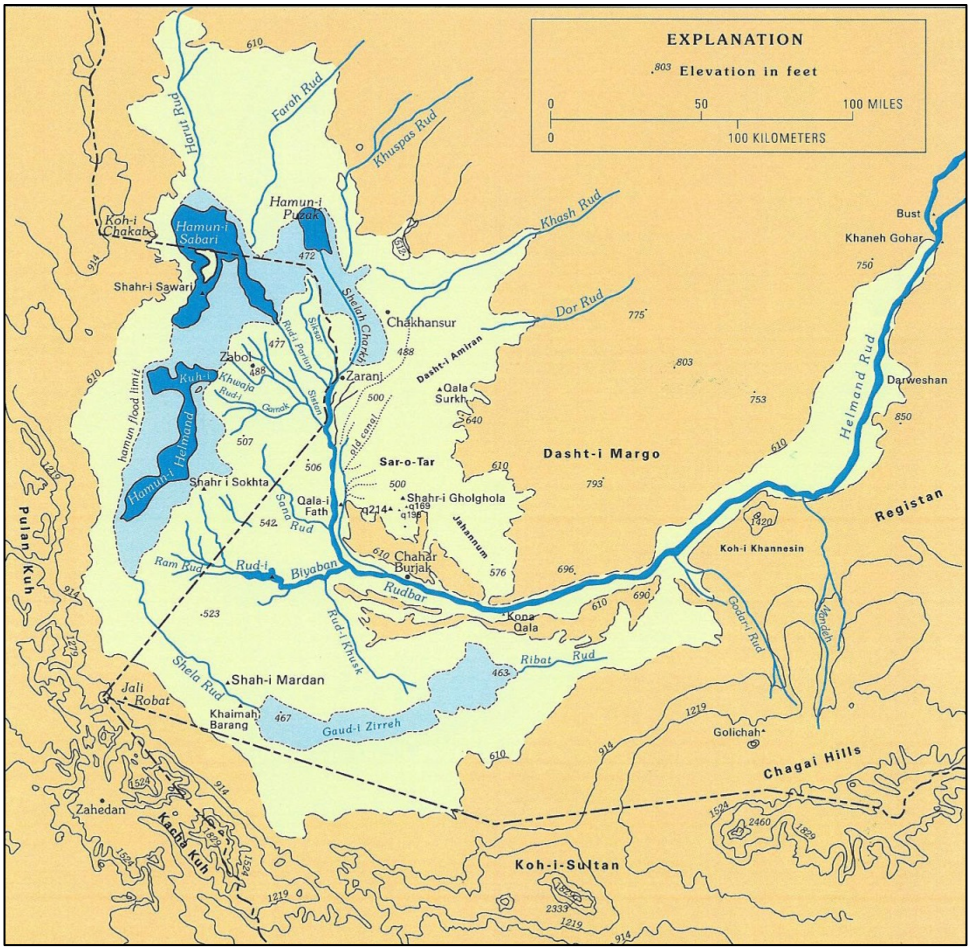
The principal river is the Helmand (or Hirmand) which flows from the Paghman Mountains just west of Kabul to end in Sistan after a journey of 1,400 km. Along with the Hari or Tedzhen and the Aras, this is one of the few major rivers entering Iran. Snow and rain in the Hindu Kush mountains ultimately reach Sistan at 427 m from heights of 5,300 m. The Helmand is the most important river between the Tigris and the Indus and drains an area of 386,000 sq km of which 78,000 sq km or 20.2% lies in Iran (Gleick, 1993). Stone (2018) reported that it was dry apart from pulses between February and April.

Habitat of *Schizocypris altidorsalis* and *Tariqilabeo adiscus*,
CMNFI 1979-0224, Sistan, Hirmand River effluent, 8 May 1977, Brian W. Coad.


Helmand or Hirmand River basin
(Helmandrivermap, CC BY-SA 3.0, Kmusser).




Map of Sistan, to show some localities cited in Annandale and Hora (1920).



Sistan, after The Center for Afghanistan Studies, University of Nebraska, Omaha, by permission of S. Rahmanzai.

The Helmand produces 1,700-2,000 cu m per second in flood and 56 cu m per second in the dry season. The average annual flow is 78 cu m per second. The river varies between 200 and 900 m in width and between 2 and 5 m in depth. The annual water income to Iran is about 6 billion cu m but this varies markedly and was as high as 14,740 million cu m in 1970-1971 and 1976-1977 (Mansoori, 1994). UNEP (2003) gave the following flows in million cu m:-

| 1991-2 | 1992-3 | 1993-4 | 1994-5 | 1995-6 | 1996-7 | 1997-8 | 1998-9 | 1999-2000 | 2000-1 |
|---|---|---|---|---|---|---|---|---|---|
| 2,211.7 | 1,783.8 | 529.5 | 829.7 | 1,023.8 | 908.7 | 2,193 | 258.8 | 114.1 | 48 |

As it enters the Sistan depression, the Helmand splits into several branches which feed the swamps, the two main ones being the Sistan feeding the Hamun-e Helmand (also Hirmand or Hamun Lake) in Iran and the Parian feeding the Hamun-e Puzak (or Parian) lying mostly in Afghanistan. The northern part of the Hamun-e Helmand is called Hamun-e Sabari, or Lake Sistan, which lies half in Afghanistan and half in Iran, and the southern part is called Hamun-e Hirmand. Hamun-e Sabari receives water from the Farah River and overflow from Hamun-e Puzak. The Hamun-e Hirmand receives water from the southern or Sistan branch of the Hirmand

River and overflow from Hamun-e Sabari. Other rivers flowing from Afghanistan are the Harut, Khospas and Khash but their flow is minor and intermittent compared to the Helmand (Gabriel, 1938). The whole lake area of Sistan is often called the Hamun Lake.

The plentiful natural flow of the Helmand is reduced by irrigation dams in Afghanistan; the Arqhandab and Kajaki dams extract about half of the 12 billion cu m which enter the Afghan plain (Michel, 1973; Mansoori, 1994; Mojtahedzadeh, 2001; Delevar and Booij, 2020). A third dam was under construction in Afghanistan without environmental considerations being taken into account (World Conservation Monitoring Centre, 1990). The proposed Kamal Khan Dam on the Helmand in Afghanistan and the *Sistan Drainage and Irrigation Completion and Rehabilitation Project* in Iran would lower water level in the lake complex. There were also plans to divert water from the Sistan area to the city of Zahedan in the south. Floods in spring 1991 destroyed the Kajaki Dam and associated irrigation controls and the lakes were more extensive than they had been in over a decade. Rainfall in Afghanistan increased flow of the Helmand in 2003 and some flooding was expected in Sistan (*Islamic Republic News Agency*, downloaded 23 April 2003). The Helmand was dry at the Iran-Afghanistan border in 2004 (Gall, 2004). Sadeq (1999) listed several factors which threatened the Hamun Lake namely, fluctuation in incoming water, sedimentation, exotic species, urbanization and increased population pressure on the hamun resources. Dudgeon (2020) stated that the hamun wetlands were mostly barren salt flats with a few water storage reservoirs.

Afghanistan, Kajaki Dam (CC0, U.S. Army Corps of Engineers).

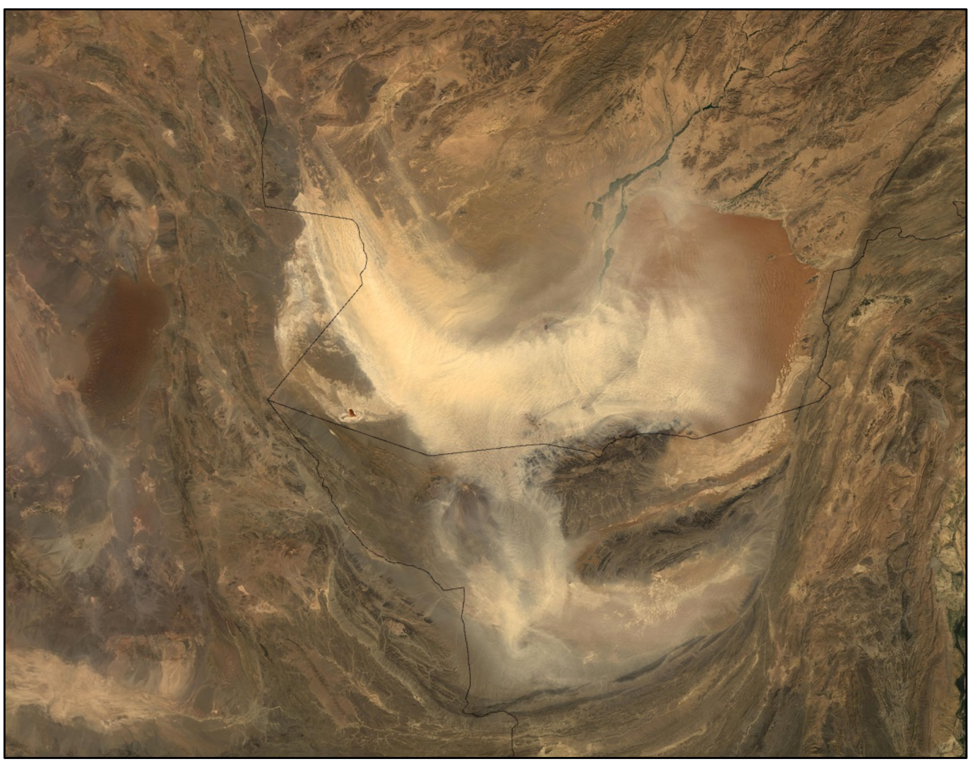
The Chahnimeh Reservoir(s) (or Char-Neimeh Lake) form a depression, used as a series of water reservoirs, and are filled from the Parian branch of the Helmand. They are variously referred to in the singular and plural in the literature and samples may be from only one reservoir unspecified. These reservoirs have a surface area of 4,700 ha and are used for irrigation, potable water for Zabol and Zahedan and fish culture but do reduce flow into the hamuns. Homayoun

Nezhad *et al*. (2007), Homayoonnezhad *et al*. (2008) and Miri (2018) gave water quality details, finding dissolved and suspended solids, hardness, turbidity and conductivity are all high from atmospheric conditions, high temperatures, sand storms and bed soil while other parameters were acceptable. The best water quality was in three cold months (January-April) and the worst was in August. Water quality varied between the four reservoirs. Rajaei *et al*. (2012), Rashki Ghaleno *et al*. (2015), Sayadi *et al*. (2015) and Bazrafshan *et al*. (2016) examined the reservoirs for heavy metal contamination finding in general that levels do not exceed international guidelines, except for cadmium, and the lakes were moderately polluted from agricultural fertilisers and natural sources. Zolfaghari *et al*. (2016) measured mercury levels in fish, water and sediments of the Hamun International Wetland, finding fish muscle and kidney levels of 0.28 and 0.32 mg/kg respectively in *Cyprinus carpio*, 0.34 and 0.36 mg/kg in *Schizocypris altidorsalis* and 0.36 and 0.41 mg/kg in *Schizothorax zarudnyi*, all at internationally acceptable concentrations. Ghaleno *et al*. (2017) described water allocation from the reservoirs for domestic, agricultural and environmental uses. Stone (2018) maintained that diversions to fill the Chahnimeh Reservoirs dried the hamuns.

Sistan in drought May 2001, with Chahnimeh Reservoirs

(dark, lower middle right)
(CC0, NASA).

Sistan, a Chahnimeh Reservoir
(Chahnimeh (in Farsi), CC BY-SA 3.0, Rasool abbasi17).



Sand storm on the borders of Iran (left), Afghanistan and Pakistan, Helmand River flowing from top right in green (CC0, NASA).

The south end of Hamun-e Puzak, and the contiguous Hamun-e Sabari (or Lake Hamun), are Ramsar Sites (World Conservation Monitoring Centre, 1990). The Lake Hamun Ramsar Site is on the threatened list of National Parks (Anonymous, 1988a).

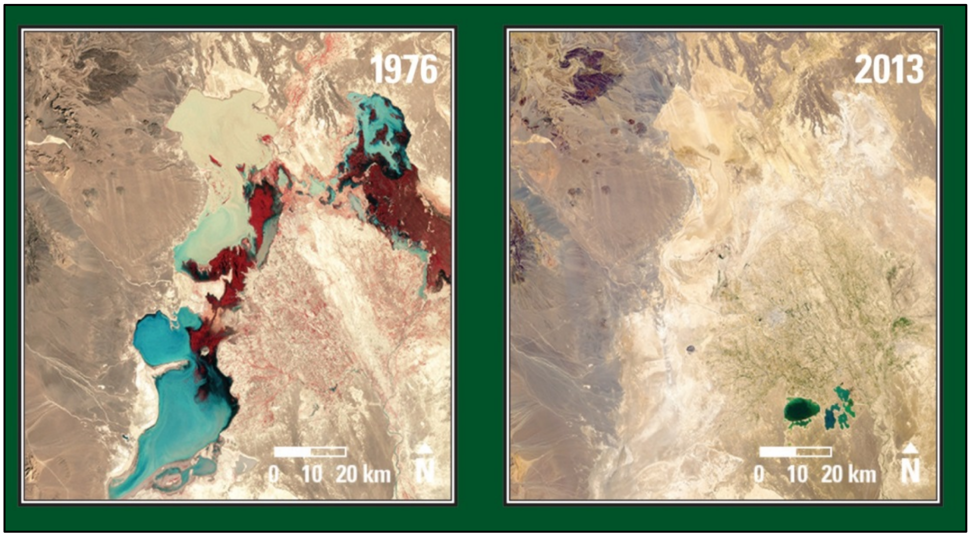
Puzak is very shallow, with maximum depth of less than 4 m, and is the first of the Sistan lakes to flood and may never dry out completely unlike the other lakes (Khan *et al*., 1992; Scott, 1995). However, Stone (2018) reported this lake to be dry. It had extensive reed beds of *Phragmites australis* with associated submerged *Ceratophyllum demersum* and relatively little open water. Reeds are cut as forage for cattle, burnt to improve grazing for livestock, used for boats, for wind-breaks and for cooking and heating. Local people engage in fishing. The Iranian portion encompasses 60 sq km compared with 1,842 sq km for the Hamun-e Hirmand.

The Helmand River is very turbid and deposits 8 g of silt for each litre of water (Fisher, 1968). The sediment load in 1975-1976 was 15,149,000 t and in 1985-1986 280,000 t (Mansoori, 1994). Drinking water looked like milk! (personal observations, 1977). Rain accounts for little input to the lake, the annual mean precipitation over 12 years being only 51 mm, most rain falling within 10-15 days (Mansoori, 1994). UNEP (2003) reported evidence of pesticide pollution in the Helmand and the swamps, e.g., dieldrin. Zolfaghari and Delsouz (2016) determined lead concentration in water, sediment and fish from the Hamun Wetland. Concentration of lead in water between three sampling stations was the same but differed in the sediments. There was no significant correlation between muscle and kidney levels of lead in *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *Schizocypris altidorsalis* and *Schizothorax zarudnyi*. The last two (native) species had lead levels higher than some internationally accepted limits.

The lake bottom in Iran is clay and silt and the waters are markedly alkaline. Water at the edges of the reed swamp was 31°C on 8 May 1977 (CMNFI 1979-0226), warmer than the inflowing rivers and the irrigation ditches which were only 22°C at this time. Annandale (1919a) and Mansoori (1994) gave a brief chemistry of Sistan water. There are marked variations in conductivity, temperature, pH, oxygen, alkalinity and hardness between sites. Conductivity ranged from 1,280 to 64,000 mmhos (*sic*), pH from 7.5 to 9.15, oxygen from 0.64 to 11.0 mg/l, alkalinity from 3.6 to 165.0 mval and hardness ($CaCO_3$) 180 to 3,500 mg/l in Mansoori's water samples from the Hamun Lake.

Evaporation lowers the water level each year and is caused by extreme heat and the famous Bad-e Sad-o Bist Ruz (Wind of 120 Days) which approaches 200 km per hour. This wind causes serious erosion and marching sand dunes often block streams causing them to change channel. Evaporation has been measured at 4 m per year because of temperatures over 40°C in July (Mansoori, 1994). Refilling occurs in February-June and in flood years various hamuns are joined together into one vast lake. 75% of flooding occurs in March-May. There are about 3,900 sq km of seasonal lake and marsh at a maximum, dropping to 1,930 sq km in July-January. The maximum flood zone is about 200 km long and 20 km wide, but the lakes have dried up completely, or almost so, at least five times in the past 100 years, e.g., in 1907, 1962 for five years, 1970-1971, 1984 for four years, 1988-1989, and 1998-2002, with major fish kills resulting (Tate, 1910; Harrington, 1976; Costantini and Tosi, 1978; Anonymous, 1992a; Khan *et al*., 1992; MacFarquahar, 2001; Foltz, 2002; Weier, 2002; www.netiran.com, downloaded 18 June 2002; Boudaghpour, 2011; Sharifikia, 2013). There was a big flood in March 1989, spring 1990 and an exceptional flood in February/March 1991 (Khan *et al*., 1992). The lakes filled in 2005 (E. Penning, pers. comm., 28 July 2005). Mansoori (1994) mentioned historical floods, e.g., in 1247 A.D., and droughts, e.g., in 835 A.D. UNEP (2003) gave satellite photographs

showing variations in water extent. The fish fauna can recolonise newly-flooded marsh areas from the Helmand but population numbers in the hamun vary greatly between years.




Sistan, Hamun lakes
(CC0, U.S. Geological Survey, http://earthshots.usgs.gov).

Sistan, East Hamun-e Saberi near Afghan border, January 2005, Ellis Penning.

The centre of the hamun is only about 2-3 m deep on average with a maximum depth of 5 m at highest water level (www.bibliothecapersica.com/articlenavigation/index.html, under hamun, downloaded 24 December 2004, gave 11 m). Overflow spills into the salt flat Gowd-e Zereh of Afghanistan through the Shelah River. This flushing effect probably prevents this endorheic basin from becoming saline. The Shelah was reduced to isolated and fishless pools in May 1977. The Gowd-e Zereh is at 467 m at its lowest point.

Extensive canals and ditches form a network over Iranian Sistan and serve to irrigate and

drain fields. These waters contain fish, but may dry up. The Hirmand is dammed to feed the major canals.

Sistan, irrigation channel, July 1977, Brian W. Coad.

The open lake areas are fringed by reed beds comprised of *Typha*, *Phragmites* and *Scirpus* which are concentrated at the ends of the detrital cones of the river deltas (Costantini and Tosi, 1978). Mansoori (1994) and Ibrahimzadeh (1995) reported an absence of *Phragmites* in area which was two-thirds covered in previous studies, drought being advanced as the causative agent along with cattle grazing (Khan *et al*., 1992). Usually the reeds recover after drought but in 1991 this did not happen (probably the effects of introduced *Ctenopharyngodon idella* on the young shoots since fenced areas excluding fish showed successful reed growth). Two million fish were introduced in early January 1992 near Kuh-e Khajeh. Scott (1995) also suggested that local people may have dug up tubers to use as fuel. A major fish and bird kill occurred in November 1994 but the cause was never ascertained (Scott, 1995).


Sistan, dead reeds in Hamun-e Hirmand near volcanic mount,
January 2005, Ellis Penning.

Agricultural land around the Sistan lakes is being abandoned because of increasing soil salinity. Wind-blown salt is becoming a problem in summer and the area might suffer the same fate as the Aral Sea (Scott, 1995). A new road running between the Sabari and Helmand lakes in the Ramsar Site may impede water flow despite bridges having been constructed. A canal between Puzak and Sabari will also have major hydrological impacts.

Curiously, both the open lake and the reed beds are poor in fish but channels among the reeds and areas at the edge of reed beds are productive. The effluents of the Helmand are particularly productive and provide a refuge for fish if the lakes dry out. Annandale in Annandale and Hora (1921) gave an interesting account of the fisheries of the Sistan lakes in the early years of the 20th century. Only one species, *Schizothorax zarudnyi*, was pursued (*q.v.*) using reed boats or skiffs called *tutin* which were still in evidence in the 1970s.

Habitat of *Carassius auratus*, *Garra rossica* and *Tariqilabeo adiscus*,
Sistan, neizar with tutin or reed boat, 9 May 1977, Brian W. Coad.

The introduction of exotic species resulted in an increased fish catch in the 1980s and 1990s and the number of active fishermen was 1,090 (*Abzeeyan*, Tehran, 5(5):III, 1994, M. H. Karim Koshteh, *in litt*., 2003). However, Ibrahimzadeh (1995) reported that there was no fish catch in the lake. Local people took more fish as the population increased (4% per annum, with added impact from Afghani refugees), as transport facilities improved and as animal husbandry decreased through degradation of reed beds (M. H. Karim Koshteh, *in litt*., 2003). The *Islamic Republic News Agency* (22 March 2000) reported a catch of 7,000 tonnes from the Hamun Lake; the following figures are from M. H. Karim Koshteh (*in litt*., 2003):-

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| tonnes | 2,790 | 3,520 | 4,380 | 4,106 | 3,543 | 5,998 | 4,251 | 3,900 | 6,044 | 12,000 | 2,426 |

Meijer (2006) gave an estimated catch in a semi-wet year as high as 21,840 tons although official figures gave 9,000 t. Variations reflect drought conditions, the year 2000 being particularly severe. Fluctuations in catches make the fishery a difficult occupation. Rezvani Gilkolaei (2007) estimates a commercial catch of stocked fish at 22.5-45,000 tons/year in the whole Sistan basin.

Sistan has fish farming in various water bodies. In 2005, 1.3 million juveniles of grass carp, common carp, bighead and silver carp produced by the Zahak hatchery were stocked in farms (www.iranfisheries.net, downloaded 17 January 2005; CIRSPE, 2006b). Goldfish and silver carp are exotics found in the hamuns (E. Penning, pers. comm., 28 July 2005). CIRSPE (2006a) also listed *Rutilus frisii* (= *R. kutum*) and *Abramis brama* both Caspian Sea basin species, as being present in Sistan but this may be an error. Rezvani Gilkolaei (2007) discussed breeding of *Schizothorax zarudnyi*, culture of *Ctenopharyngodon idella*, *Hypophthalmichthys*

*molitrix* and ornamental fish breeding in this basin. Arshadi and Soltanzade (2011) provided a technical and productivity assessment of fish cultured in reservoir ponds in Sistan Province. The season for warmwater fish was 210 days, average water temperatures were 20-30°C, fish mortality was low at about 5%, production wasa about 760 kg per unit, the food conversion ratio was about 25-30, the daily growth and specific growth rates were 4.71 and 1.87 respectively, and this culture in ponds proved cost effective for poor farmers in a rural area.

Berg (1940) placed this basin in his Sistan District of the Iranian Province. It excludes the upper reaches of the Hirmand River. The schizothoracine fauna is particularly characteristic and had its origins either by descent from higher altitudes during the Pleistocene glaciations (favoured by Berg) or are autochthonous as the forms at high altitudes in the Pamirs and Himalayas rose with mountain building.

## History of Research

Written records extend back to the third millennium B.C. in Mesopotamia, the plain shared between Iran and Iraq. The Uruk IV symbol for fish (an outline of a fish) dates to 3,100 B.C. or over 5,000 B.P. Later cuneiform writings on clay tablets refer to fishes and attempts have been made to identify the species, with variable results (Scheil, 1918; Diemel, 1926; Civil, 1961; Landsberger, 1962; Salonen, 1970; Sahrhage and Lundbeck, 1992). About 324 Sumerian and Babylonian fish names have been identified referring to about 90 species (some of which are marine). Fish played a prominent part in everyday life, both as food and as religious symbols (van Buren, 1948; Salonen, 1970; de Moor, 1998; Potts, 2012).

Fishing regulations had set penalties and fishing rights were leased. Guilds of fishermen existed and transport to cities with marketing was organised. Fish were sun-dried, salted, pickled, fermented and possibly smoked. Fishermen had to deliver part of their catch to the temples or as duties. Surplus fish were sold to the public. Consumption of fish was prohibited on certain days (Sahrhage and Lundbeck, 1992). See also Coad (2010, 2018), the *Freshwater Fishes of Iraq*.

The Babylonian Epic of Creation mentioned nets and splitting fish for drying. Amulets and cylinder seals depicting fish are common. A hymn which praised Ishtar of Uruk gave the result of her favour as “whole channels are filled with fish, the channels swarm with fish and with dates”. Fish were offered as sacrifices to gods and as part of funeral rites, as symbols of life and its renewal, and of fertility (Wright, 1990). The amount of fish required was clearly stipulated and whether it should be fresh, roasted or dried. The commoner species were requested by the basketful but rarer species were requested by numbers so a practical knowledge of diversity existed in the distant past. So numerous were sacrificial offerings that at Uruk I the floor of a room or court was covered with a thick layer of fish scales and fatty waste that gave it a deep golden-yellow tinge. Some areas had layers of compacted fish, 4-5 cm thick, comprising skeletons, skin and scales, indicative that these were not kitchen wastes but were sacrifices (van Buren, 1948). An Assyrian king would have 10,000 fish served at a banquet, although these were cheaper food items and the Sumerians favoured large, plant-eating carps from muddy pond bottoms (de Moor, 1998).

The Gohar Tepe archaeological site in Mazandaran dates back 5,000 years and showed evidence of freshwater fish use by the inhabitants (Sheykhshoaei and Mousavi Kouhpar, 2017).

Archaeological remains containing fish bones at Abu Salabikh, Iraq, dated to 3,000 B.C. (and summarised for south Mesopotamia), have been identified to include *Barbus* (= *Arabibarbus*) *grypus, Barbus* (= *Luciobarbus*) *esocinus, B.* (= *Luciobarbus*) *kersin, B.* (=

*Luciobarbus*) *xanthopterus*, *B.* (= *Carasobarbus*) *luteus*, *Barbus* (= *Mesopotamichthys*) *sharpeyi*, *Aspius* (= *Leuciscus*) *vorax*, *Acanthobrama* (presumably *A. marmid*), *Cyprinion* sp. (presumably *C. macrostomus*), and *Alburnus* sp., among the cyprinoids.

Radcliffe (1926), Salonen (1970) and Sahrhage and Lundbeck (1992) reviewed fishing in Assyrian and Sumerian-Akkadian times using nets, spears, traps, weirs and copper hooks and line. Contracts concerned with fish ponds date from the reign of Darius II, in 422 B.C., and with fishing in 419 B.C. *Ea*, the god of water dating back to Sumerian times, for which a fish-god or man-fish was a symbol, is still to be seen on ancient monuments in Iran (see also Green (1986)). The Middle Elamite rock relief at Tall-i Bakun near Persepolis in Fars depicts a river filled with fish but these are highly stylised and not identifiable to species. The reliefs at Seh Talan are clearer and have a stylised river floor with fishes, presumably mirroring the Fahlian River below the cliff.

Fars, Elamite rock relief of Kurangun, Seh Talan village
(Kurangun central panel and floor, 2009-05-08, CC BY-SA 2.0, dynamosquito).

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Standard of Ur, Royal Graves at Ur, Sumeria, 2600 B.C., British Museum,
Brian W. Coad.

Assyrian fisherman about 700-692 B.C., Southwest Palace, Nineveh,
British Museum, Brian W. Coad.


Fars, Pasargadae, protective spirit wearing a fish-skin cloak,
ca. 550 BCE, Brian W. Coad.

Assyrian fish god from Whymper's
*The Fisheries of the World*, 1883.

Fish imagery in Iranian artwork has been reviewed by A'lam (1999), Moradi and Esmaeili (2015), Sarami and Mokhtarian (2015), Gholamifard (2018), and in detail by Moradi (2008, 2015, 2017). Many illustrations are interpretations based on the description in the text rather than a careful observation of actual specimens. Water and fish were symbols of life, fertility and blessing to ancient Persians and fish appear on rock art, sculptures, bronzes, reliefs, fabrics, carpets, bowls and other objects. Almost all are not readily identifiable to species and tend to be generalised representations of fishes, although arguably some are cyprinoid-based as these fishes have long been used for food in Iran (see under, for example, *Arabibarbus grypus*). Gholamifard

and Vatandoust (2017) and Gholamifard (2018a) referred to several gold and silver quivers from the Kalmakareh Cave in the Kashkan River basin (Elamite period) which illustrated, probably, *Garra rufa*, a bronze ax head from the Lorestan region showed most probably a *Luciobarbus esocinus*, and pottery from the same region showed a "*Barbus*" fish. Examples of bowls and plates include a 14.5 cm bowl, 12th century, from Iran in the Victoria and Albert Museum, London. The bowl has shoals of fish in a rotating design painted in black slip on a frit ware bowl under a turquoise clear glaze (www.iranian.com/Arts/July97/Design/Page6.html, downloaded 10 June 1997). Others are illustrated below.

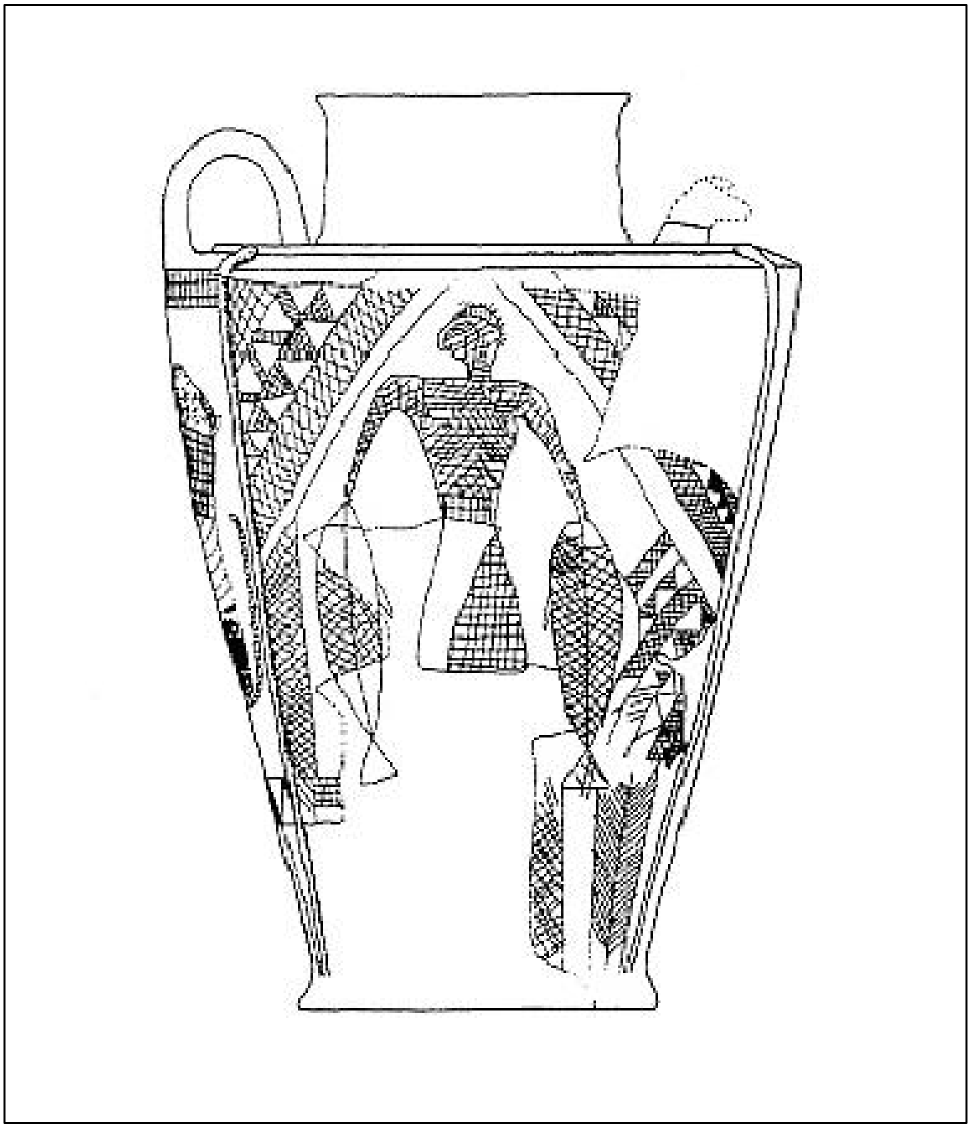
Sassanian bowl with fish, San Antonio Museum of Art
(Sama (8), CC BY-SA 3.0, Zereshk).

Gold and silver Sassanian plate showing a fishing party, Iran Bastan Museum, Tehran, (Gold and silver Sassanid plate2008, CC BY-SA 2.0, dynamosquito).

Glazed earthenware bowl with fish, Iran, 13th century A.D., Linden-Museum, Stuttgart (CC0, Daderot).

Some depictions of fish from archaeological collections are illustrated below courtesy of F. Biglari and the National Museum of Iran; others are from Wikimedia Commons. Fish have cross-hatching on the body, indicative perhaps of scales and presumably cyprinoids, which are important food items in Iran:-

Rython, 3rd millennium B.C., Tal-e Shoqa, Fars, F. Biglari.



Jar, 4th millennium B.C., Choqa Mish, Khuzestan, F. Biglari.


Chlorite vessel, 3rd millennium B.C., Jiroft, Kerman, F. Biglari.

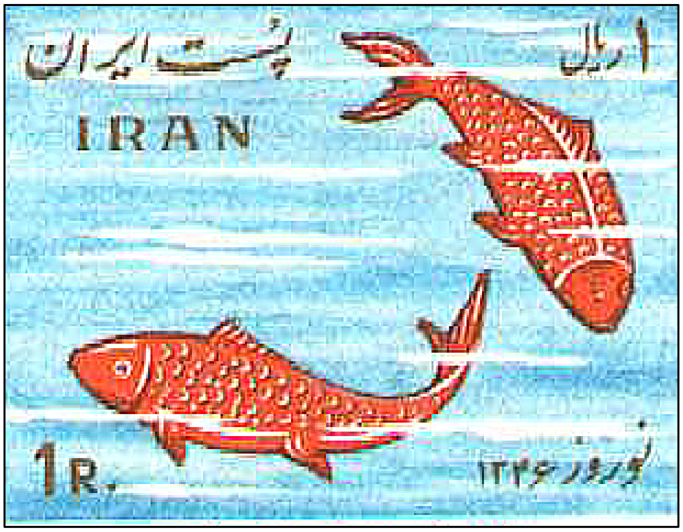
Copper coin from Rasht, showing the Zodiac symbol for Pisces, the 12th month in the Persian calendar, 20 February to 20 March.

Fish also appear on various forms of modern artwork and such national symbols as stamps.


Iranian stamps with two cyprinoid species and three other species often mentioned herein, Brian W. Coad.

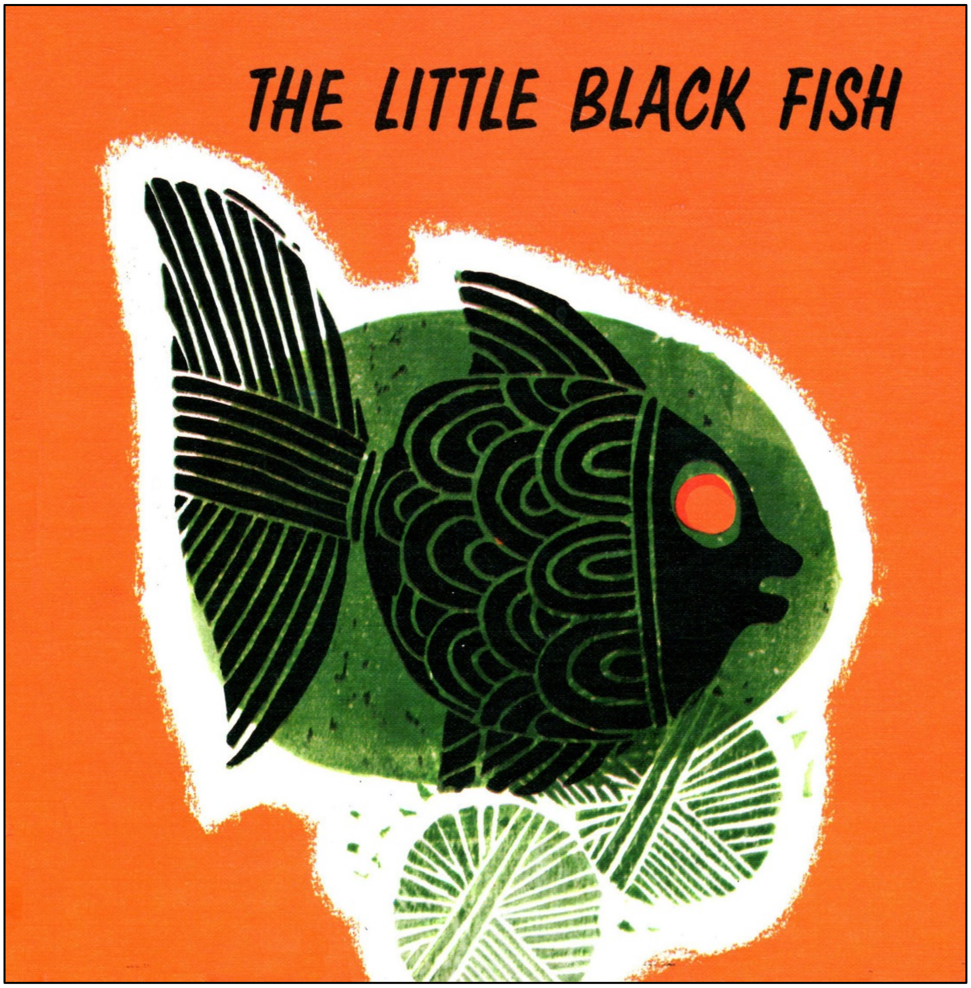

Iranian stamp with *Cyprinus carpio* (mahi kopur),
Brian W. Coad.


Iranian stamp with *Rutilus kutum* (mahi sefid)
Brian W. Coad.



Iranian stamp for Now Ruz (New Year), 1346, with goldfish
Brian W. Coad.

A famous and award-winning children's book in Iran is titled "The Little Black Fish" written by Samad Behrangi, widely translated, and illustrated by Bizhan Khodabandeh. It was considered to be a political allegory, and was banned in pre-revolutionary Iran. Black fish (siah mahi) is part of the common name for many Iranian cyprinoids. Asghari *et al*. (2019) examined the genealogy and symbols of this work.




Book cover of an English Translation, Brian W. Coad.

Governmental revenue from the Caspian fisheries have been recorded as early as 820-873 A.D. under the Taherids. Alam (No date) summarised the history of fisheries in Iran.

Arabic and Persian works contain few recognisable species of freshwater fishes although the tenth century *Kitab al-Tabikh* from Baghdad contains some fish names such as bunni (probably *Mesopotamichthys sharpeyi*) and shabbût (probably *Arabibarbus grypus*) (Perry, 1998). One of the best examples of an early scientific Islamic work on zoology is the fourteenth century *Nuzhatu-l-Qulub* (= Hearts Delight) by Hamdullah Al-Mustaufi Al-Qazwini (translated into English by Stephenson (1928)). Only the tarikh is identifiable as a freshwater fish - *Alburnus tarichi* from Lake Van in modern Turkey.

Generally, paintings of fish on historic items are insufficiently detailed to allow identification to species (see Stchoukine (1936) for some examples). An interesting painting of a fish is found on a Persian miniature of the fourteenth century stored in the Metropolitan Museum of Art, New York (Dimand, 1934) and other versions exist (Paydar Fard *et al.*, 2019). The painting shows Jonah leaving the mouth of a fish. A colour figure of this painting is found in Gould and Atz (1996), although the image is reversed and a corrected colour version is in Coad *et al.* (2000). The painting is from Rashid ad-Din's *Jami al-Tavarikh* or Universal or World History which contains accounts of various historical and mythical events, including the history of China and Mongolia, the Bible and incidents in the lives of Mohammad and Buddha. As

Dimand (1934) pointed out, this book was highly favoured by Persian painters of the fourteenth century and several copies exist, the earliest being 707 A.H. (= 1307 A.D.). The painting, dating to about 1400 A.D., shows Jonah being cast up by a fish. The text on Jonah's arms however reads “The disk of the sun entered into darkness” on the left arm and “Jonah entered the mouth of the fish” on the right arm. The former, which was taken from the *Gulistan* (= Flower Garden) of Sa`di written in 1258, being a more poetic rendering of the latter. The angel, however, appears to be offering the naked Prophet a garment, and this, as well as the proximity of terrestrial vegetation, suggests he is leaving the mouth of the fish. The fish undoubtedly was copied by the Persian artist from Chinese paintings (Rice, 1976; Blair, 1995). It most closely approximates some kind of carp but its mouth has been enlarged to accommodate the squatting figure, and the opercular opening approaches the eye too closely to make it a recognisable rendition of any particular species. There also are two dorsal fins (not found in any member of the cyprinoids), and the pectoral fins are located too far from the head. Nevertheless, the fish does exhibit a number of well-observed features such as symmetrical, overlapping scales on the body with smaller ones on the caudal peduncle, paired and median fins with fin rays, and the absence of head scales and teeth.

Jonah and the fish, ca. 1400, Jami` al-Tawarikh
(Jonah and the Whale, Folio from a Jami al-Tavarikh (Compendium of Chronicles), CC0, Metropolitan Museum of Art).

Various illustrations from Persian literature have fish included, usually not sufficiently detailed or realistic to be identifiable.

Farhad (or Khosrow) presents a fish to Shirin from the tragic romance in the Khamsa of Nizami, ca. 1465, The San Diego Museum of Art (CC0).

In modern Iran, the fish is still a symbol of prosperity, blessings, abundance and happiness at *Now Ruz*, the Persian New Year on 21 March, when a live fish from a store (usually a goldfish) or local stream is kept in a bowl. In Persian mythology the earth is balanced on the horn a gigantic cow and as the New Year starts the cow throws the earth from one horn to the other. The movement of the fish in the bowl when this happens shows that the New Year has begun (Noorbaksh, 1995). Anahita, the ancient god of water, watched over people in their dealings with water and fish (Sajaadyeh, 1995).

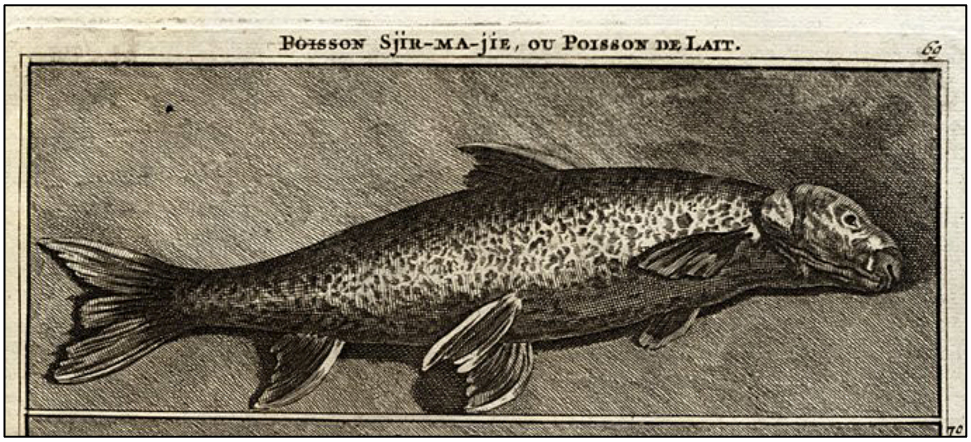
A general survey of natural history studies in the Muslim world was given by Mirza (1983), an Islamic approach to the environmental crisis by Zaidi (1981), and Islamic principles for conservation by Ba Kader *et al*. (1983).

Travelers from Europe often wrote up accounts of their visits to Persia and some commented on the fishes although such comments were mostly of a general nature and species were rarely identified. An exception is the trout near Tehran. A summary and translation into English of the earlier accounts may be found in Pinkerton (1758-1826). Adam Olearius noted that the king leased fishing in the rivers entering the Caspian. The lessees blocked the river from September to April near the mouth to catch migrating fishes. Outside this area anyone was free to fish. Sir John Chardin, in a series of English and French editions from 1686 to the early nineteenth century of his *Description of Persia and Other Eastern Nations*, briefly mentioned fishes. Both Sykes (1927) and Fraser (1825, 1834) observed the lack of diversity in a water-poor country but commented on the presence of fishes in qanats. Fraser (1825) stated:-

> "I may remark as a curious fact in zoology, that many of the cannauts, both here (i.e. at Neyshabur) and at Shahrood, swarmed with fish, some of which were of considerable size. When it is remembered that these are not natural, but artificial sources of water, brought from underground for distances of many hundreds and even thousands of yards; and that the water, after issuing into the open air, has but a short course, being either entirely absorbed in irrigating the cultivation, or lost in the barren plain beyond it, and thus having no communication whatever with any large or permanent body of water, it seems difficult to account for the presence of these fish. The natives say that they are to be found in most considerable cannauts, but are never put into them by the hand of man. It may be added, that we saw no fish in any of the mountain streams on the southern face of the Elburz, although some that we crossed were clear, and of considerable depth. The Russian soldiers, who catch these fish, observe the same fact, all are taken in cannauts, not in the natural streams. They are a leather-mouthed fish, of no great delicacy, but perfectly sweet and wholesome".

Cornelius Bruyn (1652-1726/27) (or Cornelis de Bruijn, Corneille LeBrun, de Bruin) depicted several fishes from his journey through Russia and Persia, mostly from the Persian Gulf, but including one called sjir-majie (= shir mahi or milk fish) which Heckel (1843b) identifies as *Capoeta trutta* and stated that it is from Esfahan. *Capoeta trutta* is not found near the city of Esfahan. This illustration appeared in volume 1, page 185 and plate 69 of the Amsterdam edition in French published in 1718. However, a reading of the text and examination of the illustration (slides kindly provided by Martine Desoutter of the Muséum national d'Histoire naturelle, Paris) showed that the fish cannot be identified so clearly. No scales are shown and the colour pattern is unusual and unlike any Iranian freshwater fish. The colour pattern is vaguely reminiscent of *Barbus lacerta* or a related species although much exaggerated.

The illustration is possibly based on a *Barbus s.l.* or a *Capoeta* species. The author was in Esfahan on 23 November 1703 when describing the fish but the specimen is mentioned in the same paragraph as a "Lezard de mer....prend dans le Golfe Persique" and I take this to mean that the fish too may come from a locality on or near the Persian Gulf rather than the neighbourhood of Esfahan as Heckel (1843b) has it.



Milk fish from De Bruyn (1711).

Floor (2003) devoted some considerable space to fisheries in Qajar Iran, not repeated here. The most important were for Caspian caviar. The Russians controlled much of the Caspian fishery although there were also Persian concessionaires.

The following review of scientific works on Iranian freshwater fishes necessarily focuses on European authors who described or recorded species from Iran and adjacent countries in the nineteenth and first half of the twentieth century. General reviews and fisheries studies were authored by I. Rostami (1940-1963, see **Bibliography** in Volume II), F. Farid-Pak (1957-1968), Mehrtabor (1960) and Barimani (1960-1966).


Dr. Rostami in his museum outside Ahvaz, Khuzestan, 25 January 1978,
Brian W. Coad.

Fisheries studies appeared in the 1960s and 1970s from, for example, the Iran Fish and Game Department, the Fisheries Research Institute at Bandar Pahlavi (= Anzali) and the Food and

Agriculture Organization of the United Nations (see Vladykov (1964), later Ph.D. supervisor of Brian W. Coad). Modern studies of Iranian freshwater fishes, their taxonomy and systematics, began with the theses by Saadati (1970), Wossughi (1978) and Armantrout (1980) and works by me (1979-present), although studies relevant to Iran appeared in the literature of neighbouring and European countries. The extensive and varied studies carried out by Iranian scientists in the last two decades of the twentieth century and in the twenty-first century are evident from the **Bibliography**. The Iranian Society of Ichthyology, founded in 2013, publishes two journals (the Iranian Journal of Ichthyology and the International Journal of Aquatic Biology), and provides a forum for ichthyological work in Iran with an annual conference.

Scientific works relevant to Iran begin with the *Systema Naturae*, 10th edition, by Carolus Linnaeus (1701-1778) published in 1758 and in which scientific naming in zoology has its beginning. Linnaeus adopted many of the names from the system developed by Petrus Artedi (1705-1735) who, on a visit to Amsterdam to examine a collection of fishes from the East and West Indies, drowned in one of the canals. The work of Linnaeus is widely documented. After this date a variety of papers were published by authors in many countries describing fishes scientifically and some of these fishes were eventually found to occur in Iran. Examples include Marc Elieser Bloch (1723-1799), a physician who began to devote himself to ichthyology at the age of 56, and Johann Gottlob Schneider (1750-1822) who collaborated with Bloch and published their *Systema Ichthyologiae* in 1801 after Bloch’s death. This work contained all known species at that time (Bloch also wrote *Naturgeschichte der ausländischen Fische*, 1785-1795; and lastly Franz Steindachner (1834-1919), director of the Kaiserlich-Königliches Naturhistorisches Hof-Museum (or Imperial-Royal Natural History Court-Museum - now the Naturhistorisches Museum at Vienna), who wrote so copiously on fishes from all over the world that any systematist eventually must consult his works, e.g., for the description of *Schizopygopsis stolickai* (1866) (see Kähsbauer, 1959; Adler, 1989; Herzig-Straschil, 1997). A number of fish species are named by others for Ferdinand Stoliczka (1838-1874), who collected extensively in the Himalayas and was appointed naturalist to the Second Mission to Yarkand, but who died on the way to Leh through hardships encountered on this journey (see Day, 1876, 1878).

Fish descriptions from the Middle East begin with the work of Fredrik Hasselquist (1722-1752) in his *Iter Palaestinum eller Resa til Heliga Landet Förrättad ifrån År 1749 till 1752* (= Voyage to the Holy Land Undertaken from the Year 1749 to 1752) which was published by Linnaeus in 1757 after Hasselquist “Succumbed to the fatigues and cares of the Journey” (Günther, 1869). Although this work appeared before Linnaeus’ 10th Edition and is thus rejected as far as scientific nomenclature goes, it still contains recognisable and scientific descriptions of fishes.

Alexander Russell (1715-1768), physician to the British Factory at Aleppo from 1740-1754, gave an account of undescribed fishes from modern Syria (see Russell (1794) for greater detail. The descriptions in this work are attributed to Daniel Carl Solander (1736-1782) and to Sir Joseph Banks (1743-1820) (Wheeler, 1958). Since then a number of works have appeared on Middle East fishes and although many were restricted to Syria, the Jordan River basin or drainages of Anatolian Turkey, they often contain descriptions of species also found in Iran (see **Bibliography**).

Peter Simon Pallas (1741-1811) and Johann Anton von Güldenstädt (Gueldenstaedt, Güldenstaedt) (1745-1781) described species from the Caspian Sea basin but outside Iranian waters (Pallas, 1771, 1776, 1787, 1814; Güldenstädt, 1772, 1773, 1778). von Güldenstädt was a naturalist on the expedition led by Pallas charged with exploring the Russian Empire of

Catherine II. Pallas travelled to the Urals and eastwards while Güldenstädt went south to the Caucasus, only returning to St. Petersburg seven years later (Mearns and Mearns, 1988). Güldenstädt died in St. Petersburg at only 36 years of age from fever, his resistance weakened by diseases caught in the Caucasus. Pallas based some of his descriptions on the work of Samuel Gottlieb Gmelin (1743, 1744 or 1745-1774), an explorer and Professor of Botany at St. Petersburg employed by the Russian government who visited Gilan and Mazandaran in 1770-1772, living at Anzali for some months. Gmelin died a captive of a Caucasian chieftain, the Khan of Khaïtakes. A translated account in English of his travels in northern Iran was given by Floor (2007). It included descriptions of fishes and fishing methods such as cast nets and gill nets.

Other important eighteenth and early nineteenth century authors describing and collecting fishes eventually found in northern Iran include Karl Eduard von Eichwald (Eduard Ivanovich Eikhval'd) (1795-1876) who travelled to the Caucasus and Caspian Sea including Iran (1825-1826) and collected fishes although he was prevented from landing at Anzali by the Persian Governor. Eichwald's *Fauna Caspio-Caucasica* (1841) was of particular importance as it carried descriptions of new species and recorded of a variety of other fishes. Édouard Ménétries (= Menestrier) (1802-1861) was Curator of the Zoological Collection at St. Petersburg and collected fishes in the Caucasus during 1829-1830 and reached the Talesh Mountains (Kuhha-ye Tavalesh). He listed a number of species found in the Caspian Sea and its tributaries in his Catalogue (1832).

Further to the east, there were Francis Buchanan (1762-1829) whose work on the fishes of the Ganges River in India with 269 species published in 1822 contains species later found at the westernmost extremity of their range in south-eastern Iran such as *Cabdio morar*, and John McClelland (1805-1875) who described fishes collected by William Griffith (1810-1845) with the Army of the Indus in Afghanistan including the Helmand River basin which shares waters with Iran (McClelland, 1842). The descriptions are "inadequate and highly confusing" (Hora, 1933) and some material "may have fallen into improper hands" and others "were spoiled in consequence of the jolting motion of the camels" (McClelland, 1842:561).

The most important early work on the Middle East, and specifically on Iran, is that of Johann Jakob Heckel (1790-1857), Inspector at the Imperial Royal Court Collection of Natural History in Vienna (later the Naturhistorisches Museum Wien) (Svojtka *et al*., 2009, 2012). Heckel most likely died from bacteria he was exposed to while getting a skeleton from a dead sperm whale. He described the collections sent by the botanist Theodor Kotschy (1813-1866) to Vienna from Syria which includes such places as the Quwayq (= Coic, Kueik or Kuweiq) and Orontes rivers near Aleppo and Antioch, Damascus, the Jordan River, Mosul on the Tigris River and Kurdistan (Herzig-Straschil, 1997). In addition, collections were made in Iran in 1842-1843 from around Shiraz including the streams of the Lake Maharlu basin in the Shiraz valley, the Kor River basin north of Shiraz, the Mond River (= Qarah Aqaj in its upper reaches) which drains to the Persian Gulf and Lake Parishan (or Famur) near Kazerun. (Note that measurements used by Heckel are the Wiener Zoll (= 26.34 mm) comprising 12 Linien (= 2.195 mm) as opposed to the English inch (= 25.40 mm) from information courtesy of Dr. Barbara Herzig, Naturhistorisches Museum Wien). Heckel's descriptions appeared in Joseph Russegger's *Reisen in Europa, Asien und Afrika in 1843* (volume 1, part 2) for the *Süsswasser-Fische Syriens* continued in 1846-1849 as a *Naturhistorischer Anhang* (usually dated 1847 for fishes dealt with here) followed by *Die Fische Persiens gesammelt von Theodor Kotschy* (both in volume 2, part 3). Line drawings from Heckel's works reproduced here were kindly provided by the Naturhistorisches Museum, Wien

staff (see **Acknowledgements**) as available online versions elsewhere are badly foxed. The Syrian collections contained a number of species later found in Iran. In total, 70 species were described or mentioned from Syria and many of the specimens are still to be found in excellent condition in the Naturhistorisches Museum, Wien. Note that these collections contained numerous specimens (and still do), while the catalogue in Vienna listed relatively few, presumably those which Heckel intended to be the type series. Heckel's publications often do not give accurate counts of the specimens on which the species is founded. It is not always evident which specimens are types and the whole series from a type locality is regarded as syntypes. The Naturhistorisches Museum Wien (NMW) maintains an online Ichthyology Type Database which contains details of Iranian cyprinoid types along with photographs, x-rays and maps. Note that the type locality for a number of species in the Database (downloaded 9 July 2016) was given as "Qara Aqaj [Qareh Aghaj], tributary of Shirin Rud, tributary of Dalaki Rud, tributary of Helleh River". This is incorrect as the Qarah Aqaj is the Turkic name for an upper reach in the Mond or Mand River basin, separate from the Helleh River basin.

The dating of Heckel's works is not clear for the *Naturhistorischer Anhang* and the *Die Fische Persiens*…. parts which have 1846-1849 on the cover. According to the *International Code of Zoological Nomenclature* the final date is the correct one if it cannot be demonstrated that parts of the work have their own dates. The copies of Heckel's works I have seen (mostly xeroxes) do not seem to have individually dated parts or sections and so I had used 1849 for the date whereas many earlier authors have used 1846. The *Catalog of Fishes* (downloaded 15 November 2015) and the Naturhistorisches Museum Wien favour 1847. This does not have any significant taxonomic complications as there are no other works with potential synonyms in this date range.

The nominal Iranian species numbered 22 and these too may be found in Vienna. Of 89 species described from Syria and Iran (two were deemed to be found in both countries and a third is listed merely as the trout), 72 were described as new species by Heckel, although all are not now recognised as valid. The Iranian cyprinoids still considered valid number 24 species (see Checklists for these Carps and Minnows), some described from Iran, others originally from Syria and later found in Iran.

Some of this material was sent on exchange or as gifts to other museums although it is not always clear in their records whether the material comprised types, e.g., the Muséum national d'Histoire naturelle, Paris contains specimens marked from Vienna or Heckel of *Alburnus sellal* from Persepolis (*sic*, possibly a Heckel species re-identified as *sellal*) (1638), *Chondrostoma regium* from Mosul (1635), *Cyprinion kais* from Mosul (1641), *Cyprinion tenuiradius* from Perse (1640), *Garra rufa obtusa* from the Tigris (1633), *Garra rufa rufa* from the Orontes (1634), and *Squalius lepidus* from Mosul (1636). The Museum für Naturkunde, Universität Humboldt, Berlin (ZMB) has some Heckel types listed as such, plus additional material marked as from the Wiener Museum with type localities such as Aleppo and Mosul but without dates. Some of these may also be part of Heckel's material but are not indicated as types in the catalogue. The Senckenberg Museum, Frankfurt also holds some Heckel material. All this additional material has not been investigated in detail by me as to type status, although some have been examined in these museums as indicated in the species descriptions and the *Catalog of Fishes*.

At the time Heckel's descriptions came out a series of 22 volumes was being published in Paris covering all the fishes then known. This work by Baron Georges Léopold Chrétien Frédéric Dagobert Cuvier (1769-1832) and Achille Valenciennes (1794-1865) appeared from 1828 to

1849 and was a seminal work in ichthyology, the *Histoire naturelle des poissons* (see Bauchot *et al*. (1990) for more details). It contained new species and summaries of descriptions by other authors for a total of over 4,500 fishes. New species from Iran were collected by Pierre Martin Rémi Aucher-Éloy (1792/3-1838), a French botanist and printer, who traveled extensively in Iran from 1835-1838, eventually dying at Julfa in Esfahan from "an excess of zeal for natural sciences" (Jaubert, 1843; Cuvier and Valenciennes, 1828-1849 (1844:298); Bauchot *et al*., 1990). In 1835 he traveled from Baghdad to Hamadan, Esfahan, Tehran and Tabriz and in 1837-1838 he visited Shiraz, Bushehr, Bandar-e Abbas, the Bakhtiari mountains and the south coast of the Caspian Sea. The fishes he collected were *Leuciscus maxillaris* (= *Alburnus sellal*), *Leuciscus albuloides* (= possibly *Alburnus chalcoides*) and *Chondrostoma aculeatum* (= *Capoeta aculeata*) but collection data were poor, stating only "rivers of Persia" or "freshwater of Persia".

A similar work was undertaken by Albert Carl Ludwig Gotthilf Günther (1830-1914) whose *Catalogue of the Fishes of the British Museum* in eight volumes appeared from 1859 to 1870 and contained new descriptions and reviewed earlier works with over 6,840 species described and over 1,680 doubtful species mentioned (https://catalog.hathitrust.org/Record/001500772). A new species, eventually recorded from Iran, was *Barbus* (= *Luciobarbus*) *subquincunciatus*, for example

Several other works appeared between these major, synoptic works of Heckel, Cuvier and Valenciennes and Günther and the next major work on Iranian fishes by Berg (1949) and these are outlined below.

Graf Eugen von Keyserling (1833-1889) joined a scientific expedition in 1858-1859 sent by the Russian Imperial Government to explore Khorasan under the direction of the acting privy councillor N. Chanikoff. The difficulty of baggage transport limited the quantity of alcohol Keyserling could carry and early fish collections spoiled so no types exist. However, he did draw cyprinoid fishes from nature and gave good descriptions of nine new species and reported two others from what is now northwest and western Afghanistan, south of Esfahan, Yazd and Khabis near Kerman. Four of the new species are still recognised:- *Capoeta gracilis*, *C. heratensis*, *Squalius latus* and the gobionid *Gobio nigrescens*.

Filippo de Filippi (1814-1867) an Italian zoologist, Professor at Turin and Director of the Museum (1848-1865), accompanied an Italian embassy to Persia in 1862 visiting Tabriz, Qazvin, Tehran, Rasht and the Caspian Sea (www.iranicaonline.org/articles/filippi-filippo-de). His companion the Marquis Giacomo Doria collected fishes as far south as Shiraz. Seventeen species were described from the Caspian basin and inland waters of Iran although locality data were poor in some instances (Coad, 1985). Valid cyprinoids are *Acanthobrama microlepis*, *Alburnoides eichwaldii*, *Alburnus doriae*, *Barbus cyri*, *Barbus miliaris* and *Squalius turcicus*.

Albert Günther, referred to above, also described collections and new species from the borders of Iran presented to the Natural History Museum (formerly the British Museum (Natural History)), London. The earliest of these was the collection made by William Henry Colvill at Baghdad which Günther referred to nine extant species in 1874, including a freshwater shark, and two new species, *Barbus* (= *Mesopotamichthys*) *sharpeyi* and the bagrid catfish *Macrones colvillii* (= *Mystus pelusius*). *Barbus faoensis* (= *Mesopotamichthys sharpeyi*) was described from Fao (= Faw) in another paper in 1896. The Afghan Delimitation Commission was dispatched by the British government to mark the western borders of Afghanistan. J. E. T. Aitchison was appointed Naturalist and made collections, mostly on the Afghan side of the border, from Sistan to the Hari Rud which were described in 1889 by Günther. Seven species were discovered, three new, of which only the nemacheilid *Paraschistura kessleri* is still

recognised as valid. Robert William Theodore Günther (1869-1940), son of Albert Günther, was the first curator of the Lewis Evans Collection (1924) which later became the Oxford Museum for the History of Science in 1935. In the summer of 1898, he made collections of a variety of animals and fossils in the Lake Urmia basin, including fishes, through the assistance of the Persian authorities and the Archbishop of Canterbury's Mission to the Assyrian Christians. These were described by Albert Günther in 1899 and comprised six species already described elsewhere and four new species of which three are still regarded as valid names namely *Acanthobrama urmianus*, *Alburnus ulanus* (and the synonym *Leuciscus gaderanus*) and the gobionid *Romanogobio persus*. The papers of R. T. Günther, containing some notes on fishes, were examined by me in the New Bodleian Library, University of Oxford in 2007.

Karl Fedorovich Kessler (1815-1881) was a Russian zoologist who helped organise the St. Petersburg Society of Naturalists in 1868 and later became its President for 11 years. Kessler worked on fishes of the Volga River and in 1877 published his important monograph on the *Fishes of the Aral-Caspian-Pontic Ichthyological Region*. Kessler described in this and earlier works a number of species now found in Iran including the still valid species *Alburnus filippii, Alburnus hohenackeri, Alburnus taeniatus, Capoeta buhsei* (from "Persia", apparently near Tehran (Berg, 1949)), *Chondrostoma cyri* and *Schizothorax pelzami* (Shah-rud River, northeastern Iran) plus a number of other species since synonymised and other valid species reported from the Caspian Sea basin but not yet recorded from Iran. Sideleva (2017) gave a biography of this scientist.

Francis Day (1829-1889), Inspector-General of Fisheries in India and Burma, was the leading nineteenth century ichthyologist of the Indian subcontinent, attaining this position from his initial career as a medical officer with the Madras establishment of the East India Company when fishes were but a hobby. His numerous studies have some items of relevance to Iran and his 1875-1878 monograph *The Fishes of India* with its 1888 Supplement and the two-volume *Fishes* in the *Fauna of British India* series contain useful data and descriptions of over 1,400 species. Few of his specimens were deposited in the British Museum (Natural History) because of conflicts with Albert Günther, the Keeper of Zoology there.

Henri Emile Sauvage (1844-1917) described in 1882 and 1884 the fishes collected by Ernest Chantre of the Lyon Museum on a scientific expedition to Syria, upper Mesopotamia, Kurdistan and the Caucasus including several new species from the borders of Iran, namely *Barbus microphthalmus* from the Kura River (= *Luciobarbus mursa*) and *Labeobarbus euphrati* from the Euphrates River (= *Luciobarbus esocinus*).

Aleksandr Mikhailovich Nikol'skii (Nikolskii or Nikolsky) (1858-1942) described in three papers the fishes collected by N. A. Zarudnyi (see below) in Iran. Nikol'skii was primarily a herpetologist, head of the herpetological department of the Zoological Museum of the Academy of Sciences in St. Petersburg, and later professor at Kharkov University in the Ukraine (Mazurmovich, 1983; Adler, 1989). These fishes included the new cyprinoid species *Capoeta fusca*, *Capoeta nudiventris* (= *C. fusca*), *Capoeta gibbosa* (probably *C. fusca*), *Aspiostoma zarudnyi* (= *Schizothorax zarudnyi*), *Barbus bampurensis* (= *C. milesi*), *Cyprinion kirmanense* (= *C. watsoni*) and *Discognathus rossicus* (= *Garra rossica*). Roselaar and Aliabadian (2007) gave a list of localities with interpreted spellings and latitude-longitude for bird records in Iran and this work helps with locating nineteenth century fish localities such as those in Zarudnyi's works. Note, however, that the latitude-longitudes differ slightly from those in the U.S. Board on Geographic Names used as the main source herein.

Serghyei Nikolaevich Kamenskii (or Kamensky) of Kharkov University published in

1899-1901 *Die Cypriniden der Kaukasusländer* in two volumes which described a number of new species, notably in the genus *Barbus,* since synonymised. The species *Romanogobio macropterus* (Kamensky, 1901) and *Rutilus kutum (*Kamensky, 1901) are now acknowledged as distinct species after being synonymised or recognised only as subspecies.

Erich Zugmayer (1879-1938) collected marine fishes along the Makran coast of what is now Pakistani Baluchistan, and in fresh waters in which he was more interested. He described, in 1912, six freshwater species including five new ones from internal and Sea of Oman basins close to or shared with those of Iran, namely at Panjgur in the Mashkel (= Mashkid) River drainage and the Dasht River drainage. A later work (1913) added additional records for Baluchistan. The specimens were deposited in the Zoological Museum, Munich (Zoologische Staatssammlung, München) but all fishes were destroyed in World War II on 25 April 1944 (Fritz Terofal, pers. comm., 1981; Neumann, 2006). Single type specimens were deposited in the Naturhistorisches Museum Wien (NMW) and the Zoological Survey of India, Calcutta (ZSI) of *Labeo* (= *Tariqilabeo*) *macmahoni* (NMW 81256), *Scaphiodon daukesi* (= *Cyprinion milesi*) (NMW 19784, ZSI F8028, ZSI F8032), and the nemacheilid *Nemacheilus* (= *Paraschistura*) *baluchiorum* (NMW 19851).

William Thomas Blanford (1832-1905) (Anonymous, 1905) accompanied the Persian Boundary Commission in 1872, publishing a two-volume account in 1876. The Commission mapped the boundary between Persia and Baluchistan. Major (later Sir) Oliver St. John, with a collector from the Indian Museum, Calcutta, also made collections from 1869-1871. Fish collections were minor and not included in Blanford's books. Part of the collections was described by J. T. Jenkins in 1910 from material deposited in Calcutta. Blanford and St. John marched from Gwadar through Jalk, Bampur and Kerman to Shiraz, with Blanford carrying on alone through Esfahan to Tehran. One new species is from what is now Pakistani Baluchistan, close to the Iranian border in the Nihing-Dasht drainage (*Scaphiodon baluchiorum = Cyprinion watsoni*) while the remaining material, comprising three new species of aphaniids, is from the neighbourhood of Shiraz.

(Thomas) Nelson Annandale (1876-1924) was founder and then Director of the Zoological Survey of India (Anonymous, 1925; Kemp *et al*., 1925; Adler, 1989). He and a co-author reviewed the fishes of Sistan (1920) collected by Colonel Sir A. Henry McMahon and other officers of the Seistan Arbitration Commission of 1901-1904 and by officers of the Zoological Survey of India in the winter of 1918. Nine species were described. The McMahon collection had been examined by Charles Tate Regan (1878-1943), later to be Director of the British Museum (Natural History), London (now the Natural History Museum) who found two new species out of five collected in his 1906 work (*Scaphiodon macmahoni* (= *Cyprinion watsoni*) and the nemacheilid *Nemacheilus rhadinaeus* (= *Paracobitis rhadinaea*)), by Banawari Lal Chaudhuri of the Indian Museum, Calcutta in 1909 who reported a new loach (*Nemacheilus macmahoni* (= *Paracobitis rhadinaea*)) and by Annandale in 1919 who described two new species of *Discognathus*, *D. adiscus* (= *Tariqilabeo adiscus*) and *D. phryne* (= *Garra nudiventris*).

Annandale's co-author on the *Fish of Seistan* was Sunder Lal Hora (1896-1955) who was to become the leading ichthyologist of India on a par with Hamilton and Day, and Director of the Zoological Survey of India. Some species in Iran are also found in India and are described in Hora's numerous works (Roonwal, 1956).

Francis Buchanan (1762-1829), a surgeon-naturalist, is referred to as Hamilton in ichthyological literature (he inherited his mother's estate and adopted the name Hamilton in

1818, although his name appears also as Hamilton-Buchanan and other combinations). From 1807 to 1814, he carried out a comprehensive survey of areas under the control of the British East India Company, including fisheries, and in in 1822 published *An account of the fishes found in the river Ganges and its branches* which includes genera and species now found in Iran. Watson and Noltie (2016) gave some history of his life and work.

A. Ya. Nedoshivin and Boris Sergeevich Iljin (1889-1958) produced two lengthy papers in Russian in 1927 and 1929 on fishery capture data for Iranian waters, forming an important historical record.

Alfons Gabriel and his wife collected fishes in the neighbourhood of Bandar-e Abbas including the Genu hot spring and the Baschakird Mountains. This material was described in 1929 by Maximilian Holly of the Naturhistorisches Staatsmuseum in Vienna and contained the aphaniid *Cyprinodon* (= *Aphaniops*) *ginaonis* and *Barbus baschakirdi* (= *Cyprinion milesi*) from fresh waters.

Viktor Pietschmann (1881-1956), originally Steindachner's assistant and later (1919-1946) in charge of the fish collection at the Naturhistorisches Museum Wien, described the mugilid *Mugil pseudotelestes* (= *Planiliza abu*) and the sisorid *Glyptothorax steindachneri* (identification uncertain) from the Tigris River basin in Iraq based on materials collected on the Mesopotamian Expedition in 1910 (Kähsbauer, 1957). Cyprinoid specimens relative to Iran form part of this material.

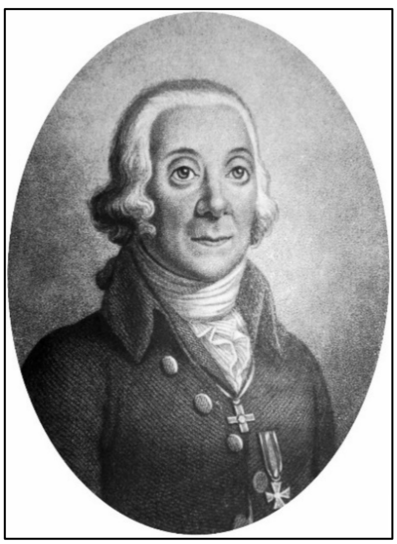
Lev Semyonovich Berg (1876-1950) was a leading Soviet physical geographer and biologist. From 1930 until his death, he was head of the Special Laboratory of Ichthyology of the Zoological Institute of the Academy of Sciences of the U.S.S.R. in Leningrad and an Academician (Oliva, 1977). His contributions to the ichthyology of the former U.S.S.R. and to that of Iran appeared in a number of shorter articles and in lengthy monographs from the late nineteenth century onwards. The shorter works are listed in the **Bibliography** and include descriptions of such new cyprinoid species as *Barilius mesopotamicus*, *Alburnus atropatenae* and *Garra persica*. His summary work *Freshwater Fishes of the U.S.S.R. and adjacent countries* was published in 1948-1949 and in English translation in 1962-1965 and has much of relevance to northern Iran, although the taxonomy is now dated. His 1940 work on the *Zoogeography of freshwater fish of the Near East* placed that fauna in context and included Iran but it was his 1949 work *Freshwater Fishes of Iran and adjacent countries* which has been the major modern work on Iranian fishes south of the Caspian Sea basin and the Lake Urmia basin. This was based on collections deposited in the U.S.S.R. Academy of Sciences Zoological Institute in Leningrad (now St. Petersburg, Russia with the acronym ZISP when examined by me, also seen as ZIN). The collections had been made by two Russian biologists. The first of these was Nikolai Alekseevich Zarudnyi (1859-1919), a zoologist and ornithologist who made four journeys to Iran for which he was awarded medals and the Przheval'skii Prize by the Russian Geographical Society. His first journey in 1896 was to Kuchan, Sistan and Mashhad, his second in 1898 was to eastern Khorasan and Baluchestan, the third (1900-1901) was to Khorasan, Sistan and Baluchestan including the Bampur region and the Makran, and the last journey (1903-1904) was to Gorgan, western Khorasan, western Kuhistan, southern Irak-Ajemi and Khuzestan. Zarudnyi's material had previously been examined and described by Nikol'skii (see above). Zarudnyi died from accidental poisoning in Tashkent at the age of sixty. The second biologist was P. V. Nesterov who worked with the Turko-Persian Demarcation Commission in 1914 and collected fishes in the Tigris basin along the present Iran-Iraq frontier. His route was mapped in Minorskii (1916).

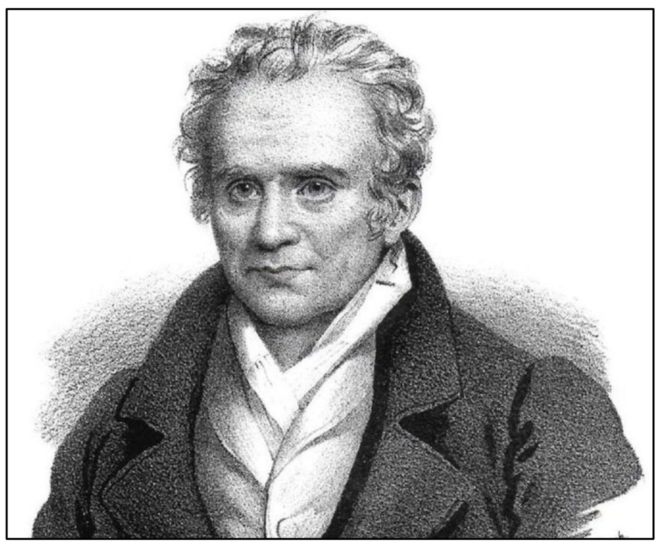
The Zoological Museum of the Lomonosov Moscow State University (MSU) contains collections from the Caucasus and Transcaucasia including the Kura River basin and Azerbaijan but none apparently from Iran (Verigina, 1991).

Anton Bruun (1901-1961 - see Spärck (1962)) was the lead author on the description of *Iranocypris* (= *Garra*) *typhlops*, the first described Iranian cave fish, later the reason and subject of popular books and articles by Anthony Smith (see **Bibliography**).

Paul Kähsbauer (1912 -1988) became head of the Fish section at the Naturhistorisches Museum Wien in 1948. He published a summary of the ichthyofauna of Iran in 1963-1964 based on literature and collections in the museum made by T. Kotschy and described by J. J. Heckel (see above) as well as more recent material collected by H. Löffler in 1949 and 1956. Mladen S. Karaman (1937-1991), from the University of Belgrade in Pristina, Yugoslavia, studied fishes in the genera *Capoeta* and *Barbus s.l.* from Turkey based on the collections in the Zoologisches Institut und Zoologisches Museum, Hamburg, the Senckenberg Museum, Frankfurt, the British Museum (Natural History), London, and the Zoological Collection of the Tr. Săvulescu Institute, Bucharest. He also revised the Middle Eastern genera *Phoxinellus*, *Leucaspius* and *Acanthobrama*. He described the genera *Carasobarbus*, *Kosswigobarbus* (= *Carasobarbus*) and *Mesopotamichthys*, and the species *Bertinius longiceps persicus* (status uncertain), *Capoeta barroisi persica* (= *Capoeta trutta*) and *Schizothorax pelzami iranicus* (= *Schizothorax pelzami*) from Iran.

Some of the earlier European authors mentioned above are shown below sourced from Wikimedia Commons (CC0 except for Pallas (CC BY 4.0) and Güldenstädt (CC BY-SA 3.0)):-



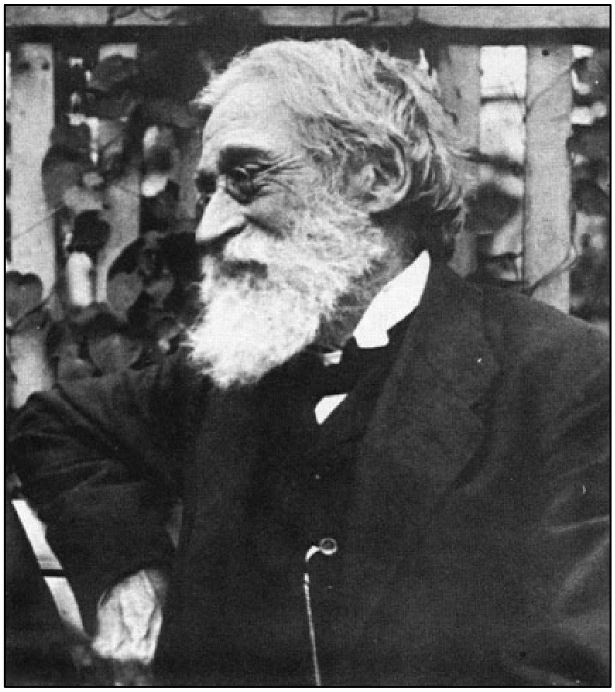


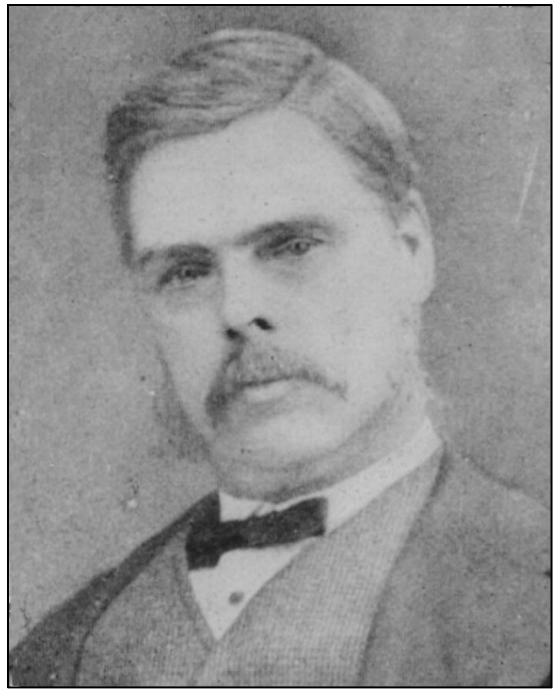
Peter Simon Pallas and Johann Anton von Güldenstädt.


Filippo de Filippi and Cornelis de Bruijn.

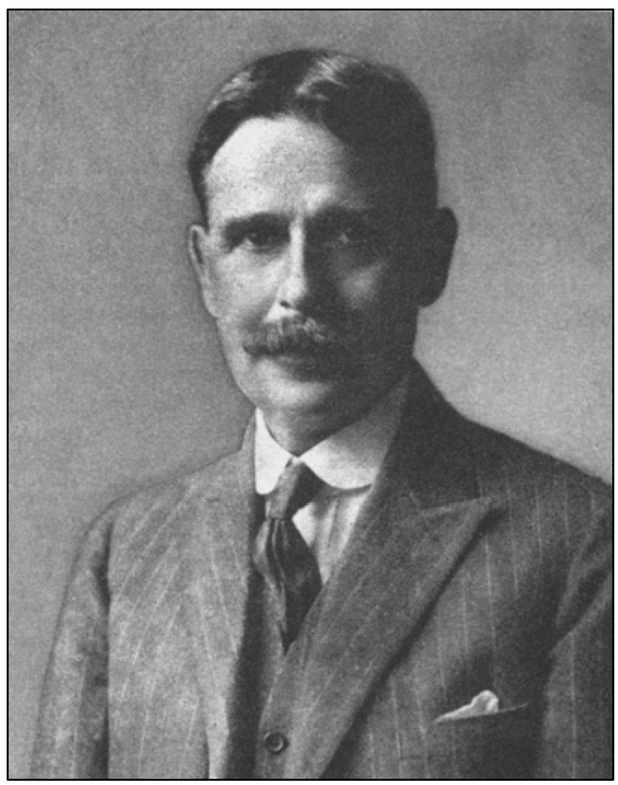


Johann Jakob Heckel and Theodor Kotschy.

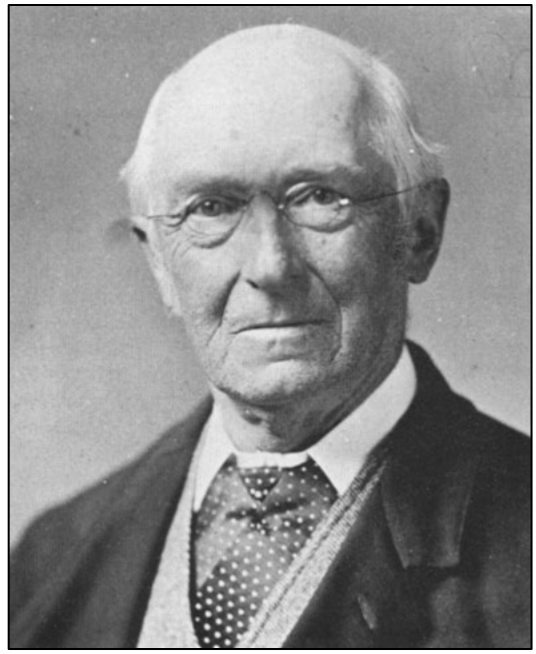




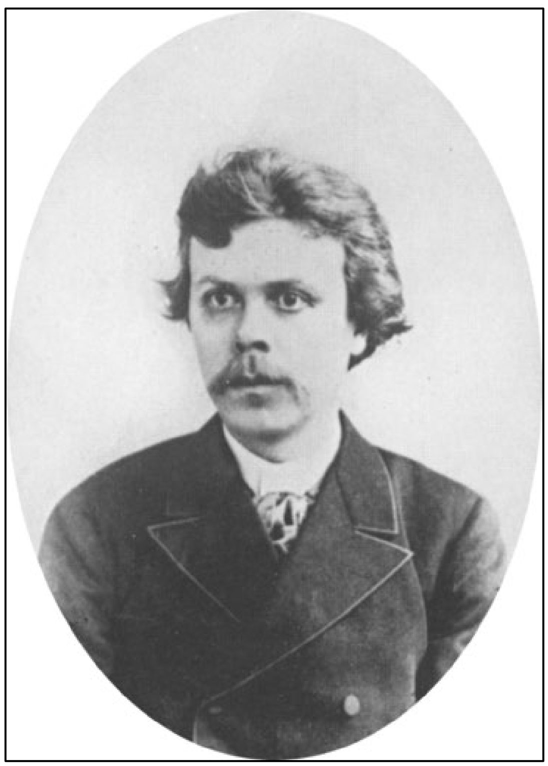
Franz Steindachner and Francis Day.

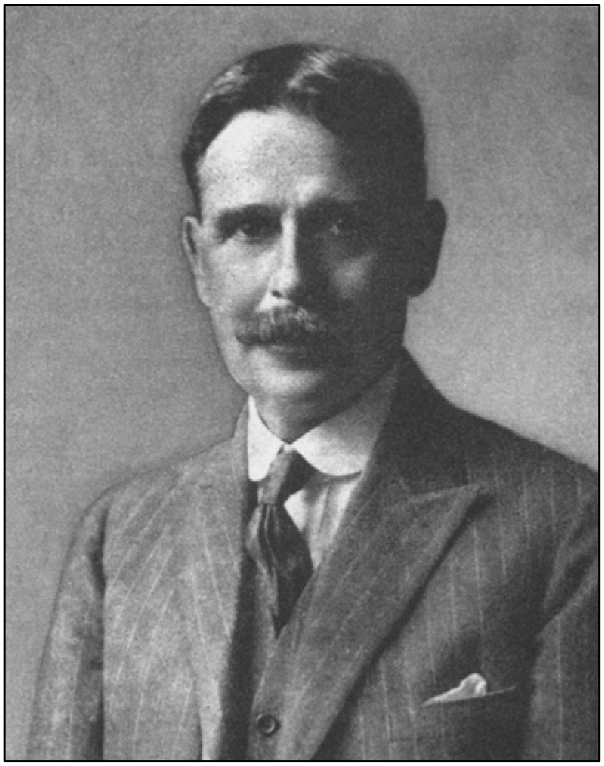
Erich Zugmayer and Nelson Annandale.

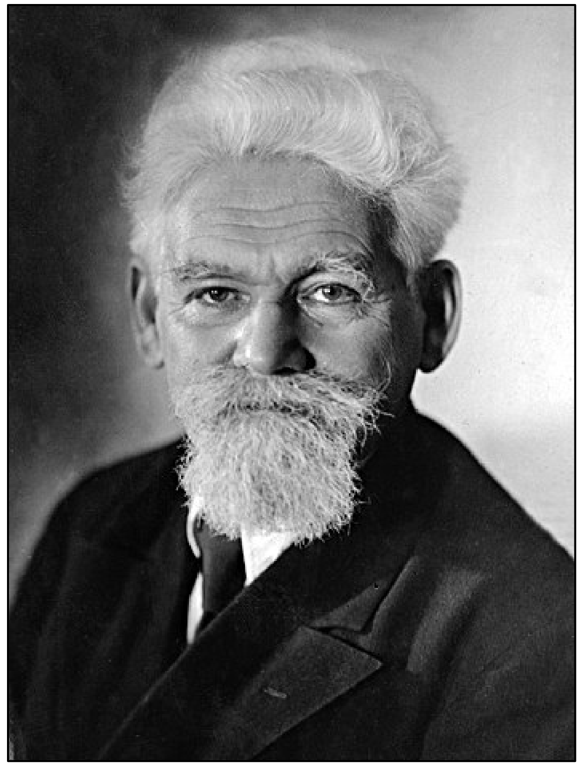



Karl Fedorovich Kessler and Albert Karl Ludwig Gotthilf Günther.



Aleksandr Mikhailovich Nikol’skii.

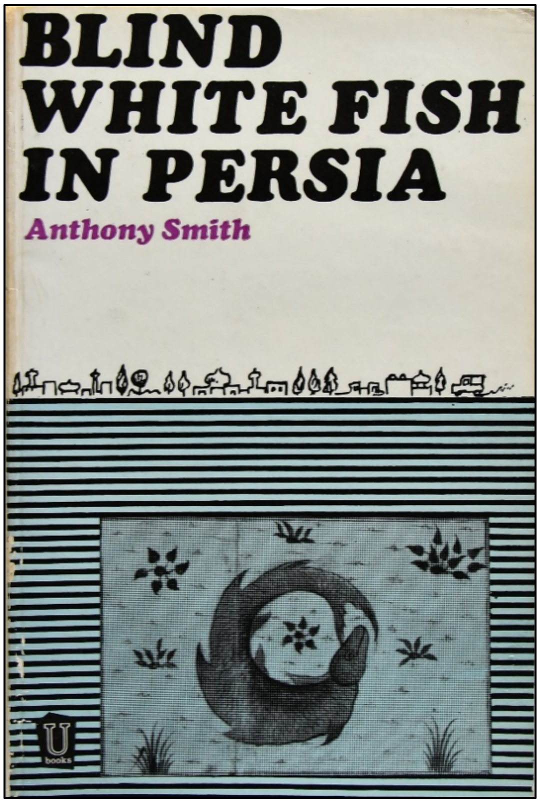


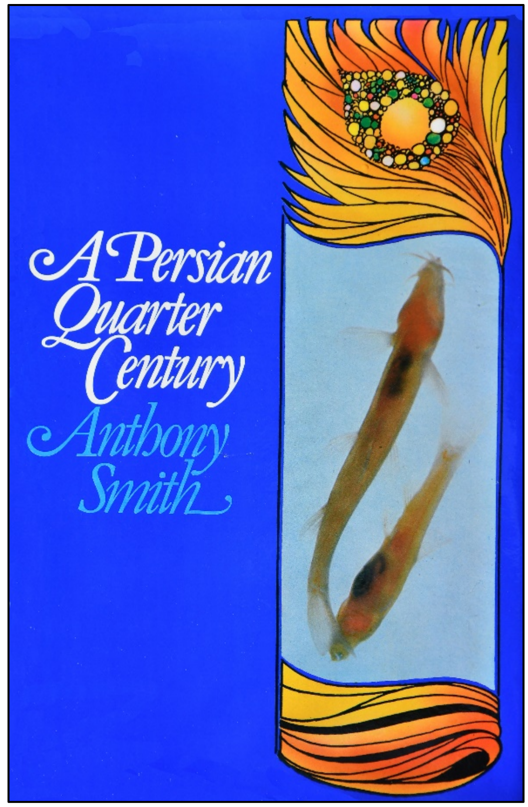


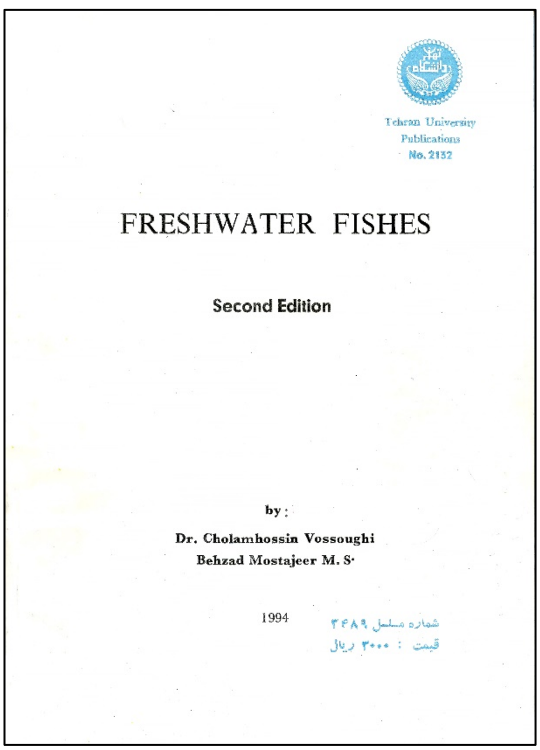
Nelson Annandale and Leo Semyonovich Berg.

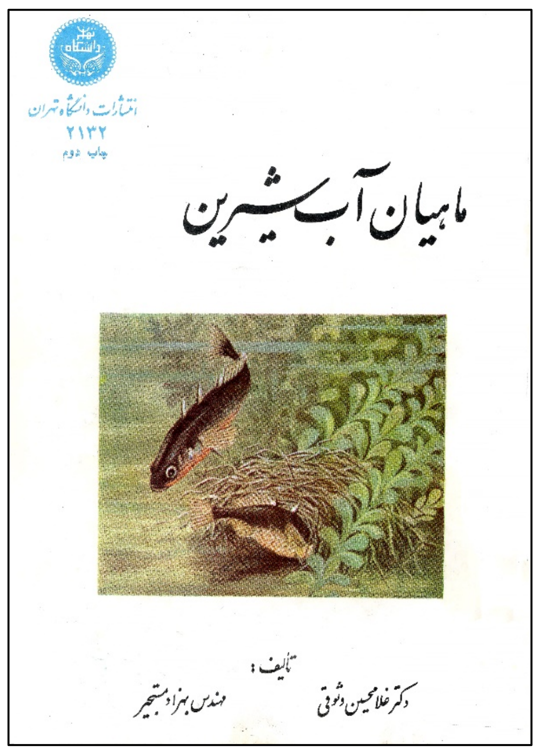
Relevant works since 1950 in addition to the above can be found in the **Bibliography** and encompass a wide range of papers and books of varying quality and utility. There has been a rapid increase in studies on fishes of Iran, starting in the 1990s. Prior to 1900, this **Bibliography** listed less than 100 publications relevant to this work, many not strictly on Iranian fishes. On a decadal basis, it is only in the 1960s that publications exceed 100 and by the 1990s are an order of magnitude larger.

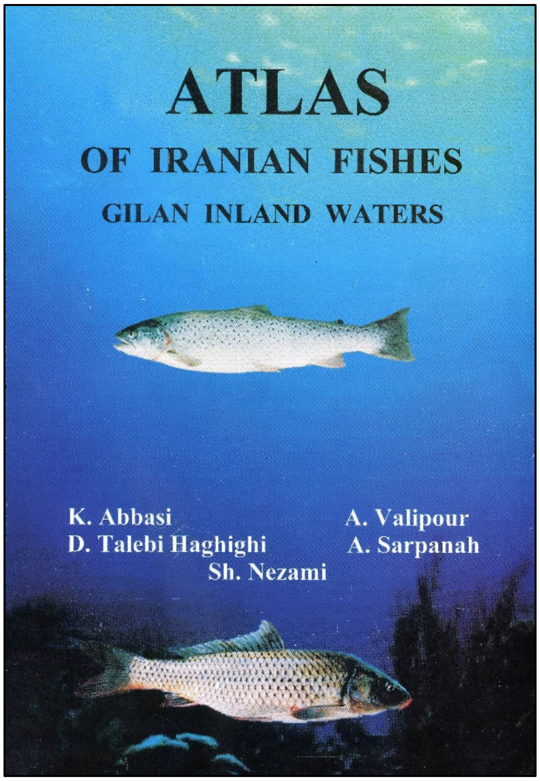
Several books have appeared in Farsi on Iranian freshwater fishes with a few in English. These include *Blind White Fish in Persia* by Smith (1953; in English), *A Persian Quarter Century* by Smith (1979; in English), *Freshwater Fishes* by Vossughi and Mostajeer (1994), *Identification of some freshwater fishes of Khuzestan Province* by Najafpour (1997), *Atlas of Iranian Fishes. Gilan Inland Waters* by Abbasi, Valipour, Talebi Haghighi, Sarpanah and Nezami (1999), *Freshwater Fishes of Iran* by Mohammadian (1999), *The Inland Water Fishes of Iran* by Abdoli (2000), *A Guide to the Fauna of Iran* by Firouz (2000; in English as *The Complete Fauna of Iran*, 2005), *Freshwater fishes of Khuzestan Province (Part II)* by Najafpour (2003), *Fish Species Atlas of South Caspian Sea Basin (Iranian Waters)* by Naderi Jolodar and Abdoli (2004), *Ichthyodiversity and its conservation in inland water of Iran* by Teimori and Esmaeili (2007), *Applied Ichthyology* by Hedayatifard and Ramezani (2007), *Biodiversity of Fishes of the Southern Basin of the Caspian Sea* by Abdoli and Naderi (2009), *Fishes of Tehran Province and adjacent areas* by Coad (2008; in English), *Fish Species Diversity of Fars* by Esmaeili *et al*. (2015, 2016), *Atlas of Inland Water Fishes of Iran* by Keivany *et al*. (2016), *The Field Guide of the Inland Water Fishes of Iran* by Abdoli (2016) and *Fishes of Guilan* by Abbasi (2017). The covers of some of these are illustrated below.

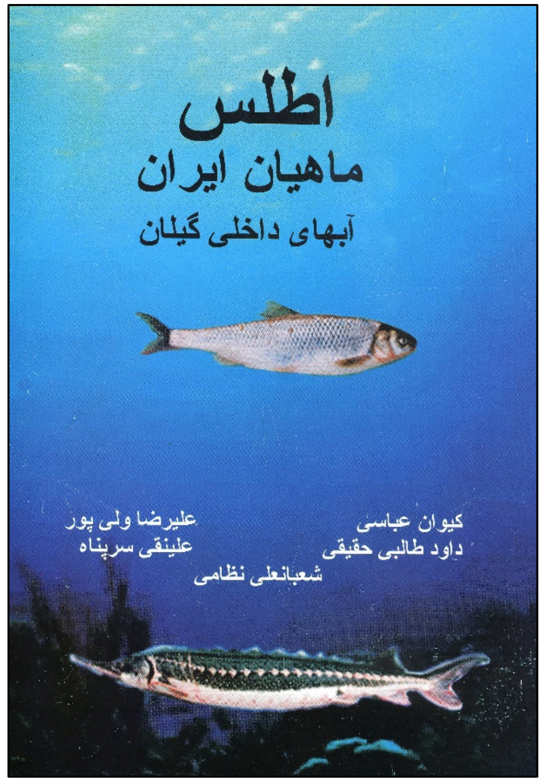

BLIND
WHITE FISH
IN PERSIA
Anthony Smith
U
books

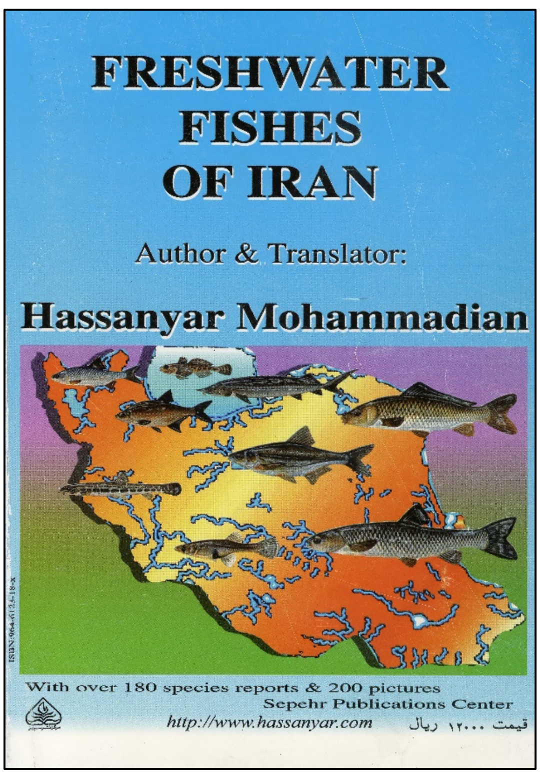

A Persian
Quarter
Century
Anthony
Smith

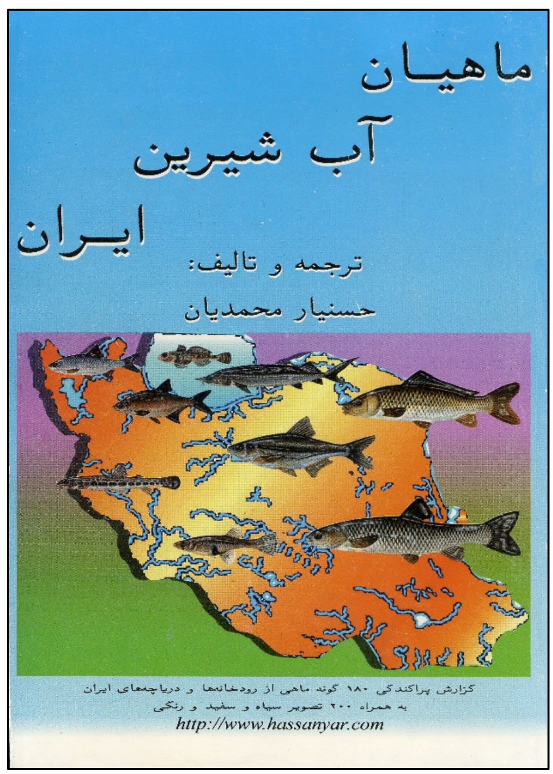

Tehran University
Publications
No. 2132
FRESHWATER FISHES
Second Edition
by :
Dr. Cholamhossin Vossoughi
Behzad Mostajeer M. S.
1994
شماره مسلسل ۳۴۸۹
قیمت : ۳۰۰۰ ریال

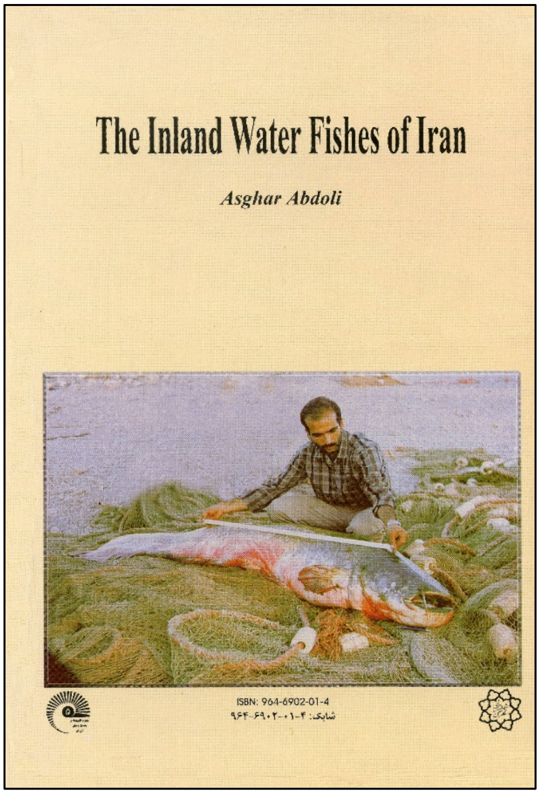

انتشارات دانشگاه تهران
۲۱۳۲
چاپ دوم
ماهیان آب شیرین
تألیف :
دکتر غلامحسین وثوقی
مهندس بهزاد مستجیر

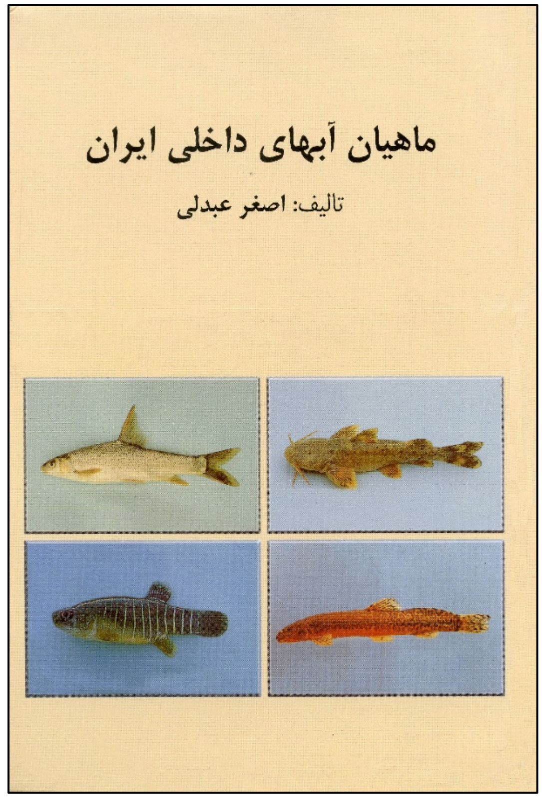

ATLAS
OF IRANIAN FISHES
GILAN INLAND WATERS
K. Abbasi
A. Valipour
D. Talebi Haghighi
A. Sarpanah
Sh. Nezami

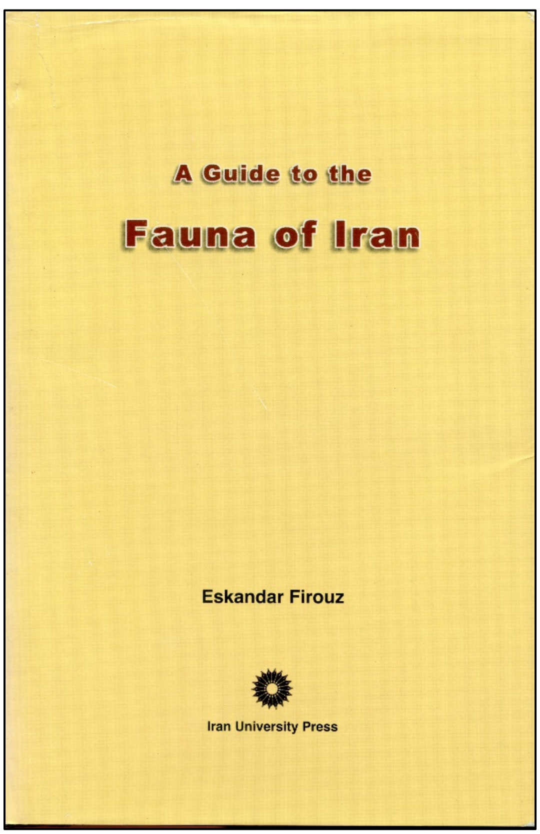

اطلس
ماهیان ایران
آبهای داخلی گیلان
کیوان عباسی
علیرضا ولی پور
داود طالبی حقیقی
علینقی سرپناه
شعبانعلی نظامی

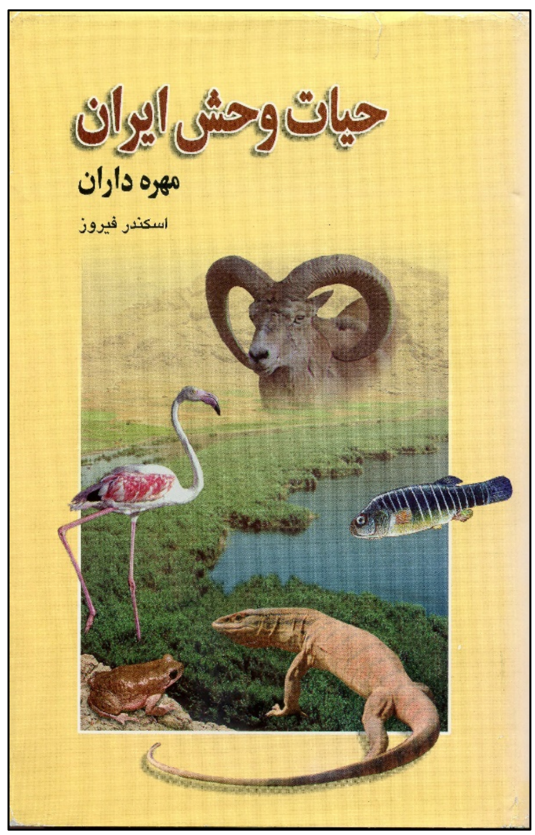

FRESHWATER
FISHES
OF IRAN
Author & Translator:
Hassanyar Mohammadian
With over 180 species reports & 200 pictures
Sepehr Publications Center
http://www.hassanyar.com
قیمت ۱۲۰۰۰ ریال


ماهیان
آب شیرین
ایران
ترجمه و تالیف:
حسنیار محمدیان
گزارش پراکندگی ۱۸۰ گونه ماهی از رودخانه‌ها و دریاچه‌های ایران
به همراه ۲۰۰ تصویر سیاه و سفید و رنگی
http://www.hassanyar.com


The Inland Water Fishes of Iran
Asghar Abdoli
ISBN: 964-6902-01-4
شابک: ۹۶۴-۶۹۰۲-۰۱-۴


ماهیان آبهای داخلی ایران
تالیف: اصغر عبدلی


A Guide to the
Fauna of Iran
Eskandar Firouz
Iran University Press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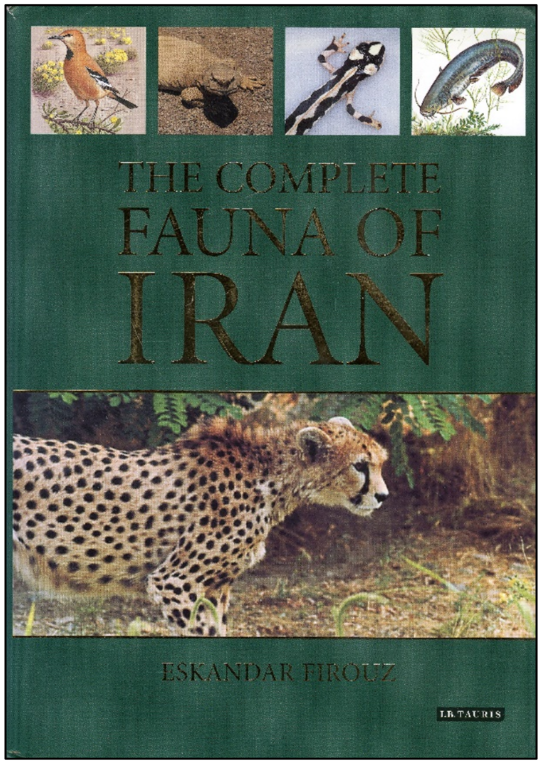
مهره داران
اسکندر فیروز


THE COMPLETE
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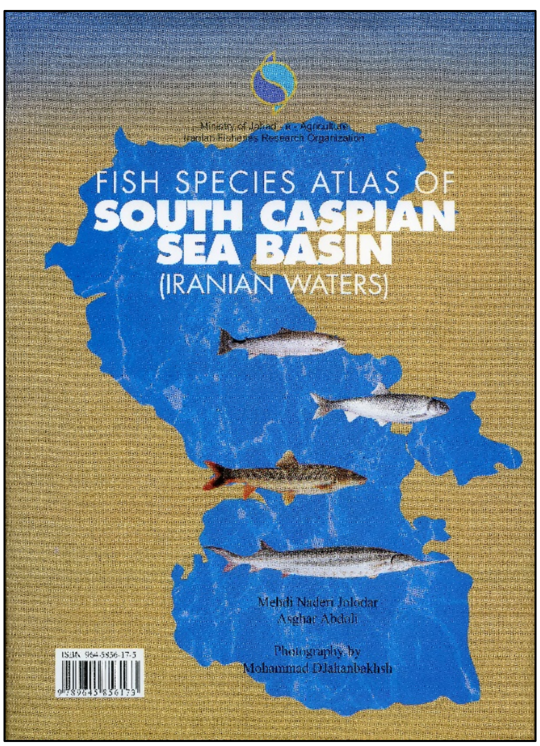
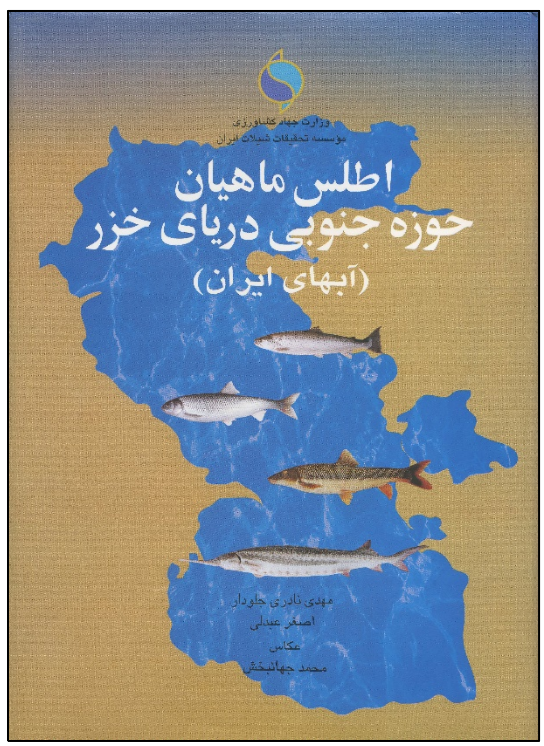
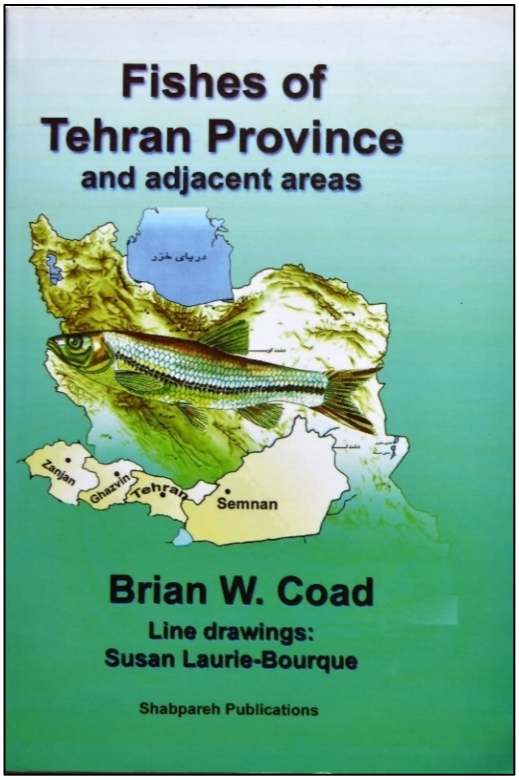
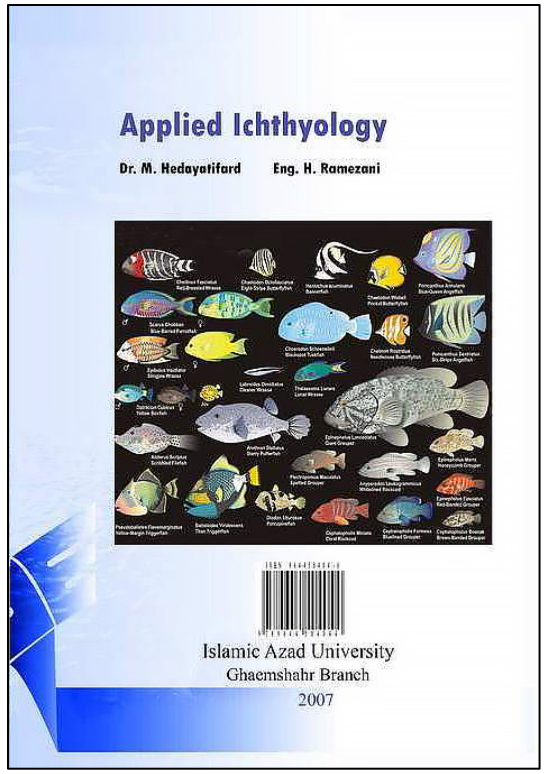
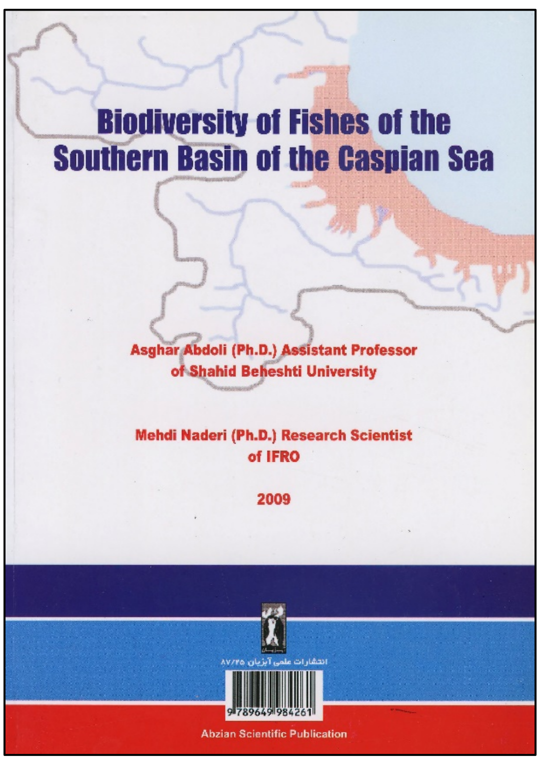
ESKANDAR FIROUZ
I.B.TAURIS


Ministry of Jahad-e-Agriculture
Iranian Fisheries Research Organization
FISH SPECIES ATLAS OF
SOUTH CASPIAN
SEA BASIN
(IRANIAN WATERS)
Mehdi Naderi Jolodar
Asghar Abdoli
Photography by
Mohammad Djahanbakhsh
ISBN 964-5856-17-5

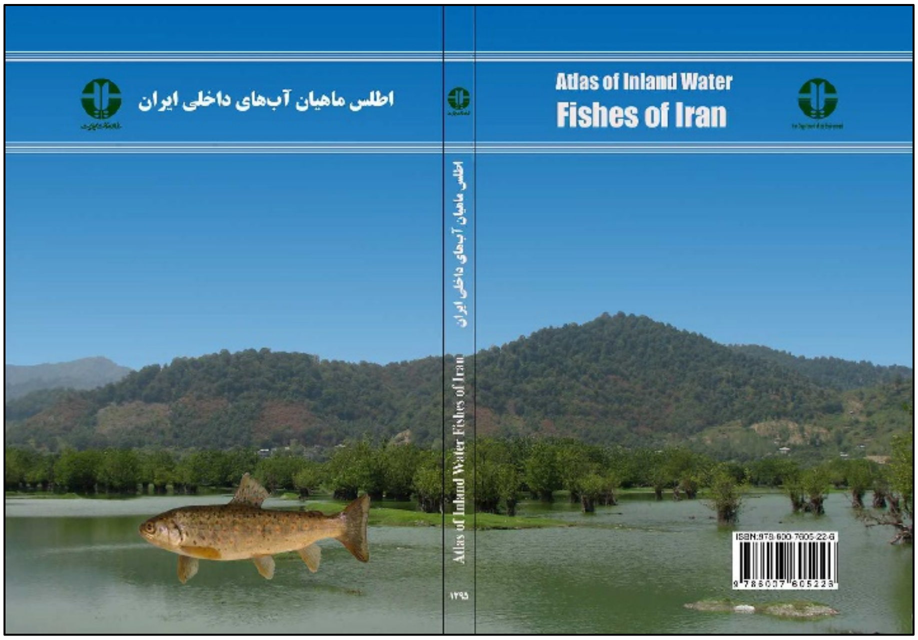

وزارت جهاد کشاورزی
موسسه تحقیقات شیلات ایران
اطلس ماهیان
حوزه جنوبی دریای خزر
(آبهای ایران)
مهدی نادری جلودار
اصغر عبدلی
عکاس
محمد جهانبخش


Fishes of
Tehran Province
and adjacent areas
دریای خزر
Zanjan
Ghazvin
Tehran
Semnan
Brian W. Coad
Line drawings:
Susan Laurie-Bourque
Shabpareh Publications

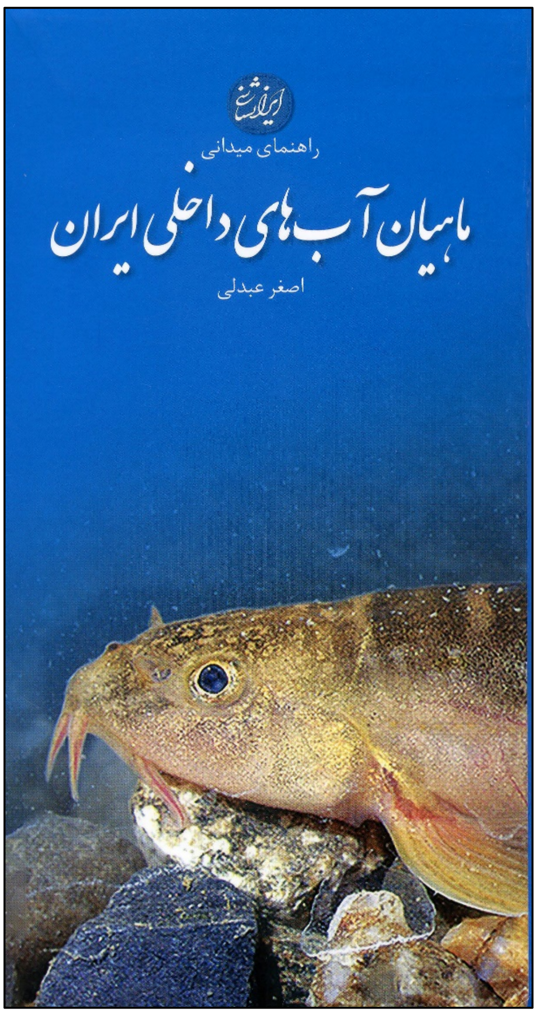

Applied Ichthyology
Dr. M. Hedayatifard
Eng. H. Ramezani
Islamic Azad University
Ghaemshahr Branch
2007


Biodiversity of Fishes of the
Southern Basin of the Caspian Sea
Asghar Abdoli (Ph.D.) Assistant Professor
of Shahid Beheshti University
Mehdi Naderi (Ph.D.) Research Scientist
of IFRO
2009
Abzian Scientific Publication


تنوع زیستی ماهیان
حوضه جنوبی دریای خزر
تالیف :
دکتر اصغر عبدلی ، عضو هیات علمی دانشگاه شهید بهشتی
دکتر مهدی نادری ، عضو هیات علمی موسسه تحقیقات شیلات ایران

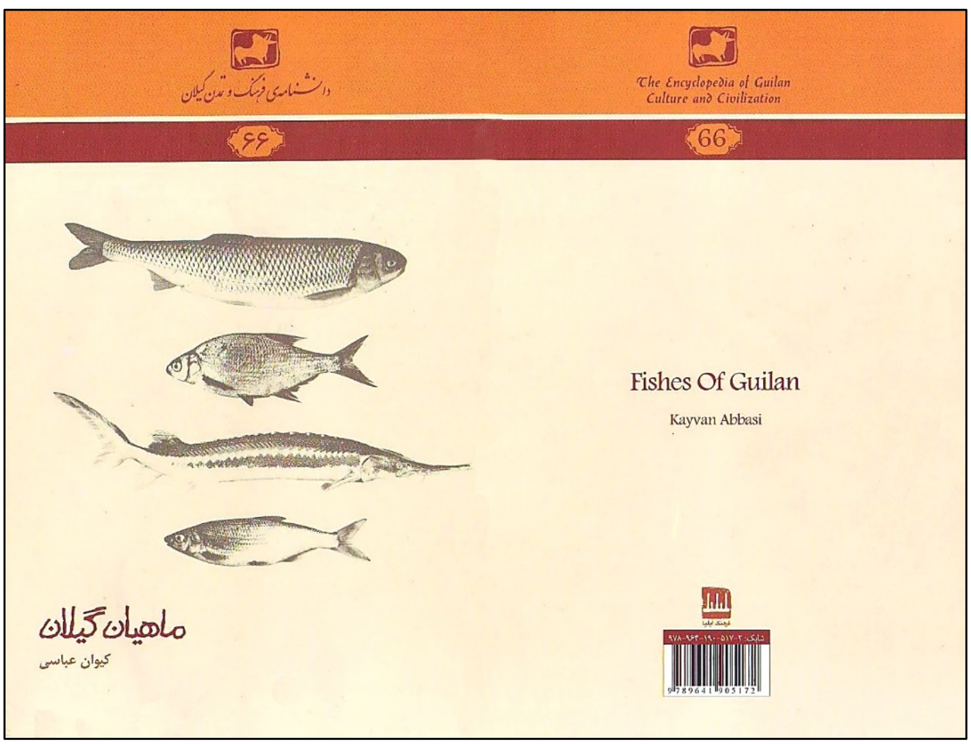


اطلس ماهیان آب‌های داخلی ایران
Atlas of Inland Water
Fishes of Iran
اطلس ماهیان آب‌های داخلی ایران
Atlas of Inland Water Fishes of Iran
۱۳۹۵

راهنمای میدانی
ماهیان آب‌های داخلی ایران
اصغر عبدلی


The Field Guide of
The Inland Water FISHES of IRAN
این کتاب براساس جدیدترین اطلاعات موجود از وضعیت ماهیان آب‌های داخلی ایران برای استفاده‌ی ساده و آسان عموم علاقه‌مندان به ماهی‌ها و طبیعت‌گردان تهیه و تدوین شده است. در این کتاب ویژگی‌های زیستی حدود ۱۷۰ گونه ماهی به همراه تصاویر رنگی، نقشه پراکنش، وضعیت حفاظتی و نحوه‌ی شناسایی هر گونه ارائه شده است. ترتیب معرفی خانواده‌ها در این کتاب براساس سیر تکاملی این جانوران انجام شده است.
کلیه حقوق مادی و معنوی این اثر اعم از چاپ، تکثیر، نسخه‌برداری، ترجمه و... برای انتشارات ایرانشناسی محفوظ و قابل پیگرد قانونی است.
تهران-خیابان طالقانی، خیابان بهار شمالی، کوچه طبا، پلاک۶، واحد ۱
کدپستی ۱۵۶۳۶۵۵۷۱۱
تلفن: ۷۷۵۳۱۸۲۵ و ۷۷۵۳۹۸۵۹
فکس:۷۷۶۳۸۶۸۷
www.iran-shenasi.com
info@iran-shenasi.com
قیمت: ۴۵۰،۰۰۰ ریال


Brian W. Coad.

In addition to books, there are various posters and informational leaflets and other publications that cannot be covered here.

A report on water laws and institutions in Iran was authored by Dezfouli (1996) and gave some background on legislation affecting fish habitats through regulation of water abstraction and pollution prevention. Koulaei and Ghoudarzi (2009) reviewed ecological threats in the Caspian Sea in light of the capacity of the Tehran Convention to decrease them.

Several general works on zoogeography of fishes have encompassed Iran as part of their study. These include Berg (1933b, 1940), Banarescu (1960, 1977, 1992b) and Por and Dimentman (1989). Most of Iran is part of the West Asian area, which includes southern Anatolia, the Levant, and the Arabian Peninsula, or an Iranian Province which excludes the Caspian Sea, Lake Urmia and Persian Gulf and Sea of Oman drainages. Berg (1940) listed the following districts within the Iranian Province:- the Tehran District (= Namak Lake basin here), the Turkmen District (= includes the Tedzhen or Hari River basin here), the Sistan District (= Sistan basin here), and a Fars District (= the rest, or the basins Dasht-e Kavir, Esfahan, Kerman-Na'in, Sirjan, Lake Maharlu, Kor River, Hamun-e Jaz Murian, Hamun-e Mashkid, Dasht-e Lut, and Bejestan here). The Caspian Sea drainage is regarded as a separate area. The fauna is a mixture of elements from the European (western Palaearctic), the Mediterranean, southern Asia, High Asia and Africa and should be regarded as a transitional region (various views briefly summarised in Mirza (1994b, 1995)). Zoogeography is dealt with here in the individual **Species Accounts** with some mention in the drainage basin accounts.

A brief history of Afghanistan ichthyology was given in Coad (1981c) and Petr (1999) with a more extensive treatment of the fauna in Coad (2014), and of Pakistan in Mirza (1978) and Bilqees *et al*. (1995). Literature, and therefore history, on Turkey was summarised in Coad and Kuru (1986), Fricke *et al*. (2007) and Çiçek *et al*. (2015), and on Iraq and the Tigris-Euphrates basin in Coad and Al-Hassan (1989), Coad (2010, 2018) and Jawad (2012). Much of the earlier Russian literature on the Caspian Sea and adjacent waters was given in Romanov (1955).

## Fisheries

Freshwater fisheries are increasing in Iran and with this exploitation there is a commensurate need for an understanding of the whole ichthyofauna. Coad and Abdoli (1996) and Coad (1998, 1999) reviewed the biodiversity of Iranian freshwater fishes and recent checklists gave updates on species diversity (Jouladeh-Roudbar *et al*., 2015; Esmaeili *et al*., 2017, 2018). Reviews of fisheries, including aquaculture, can be found in the magazine *Abzeeyan*, e.g., Anonymous (1992c) and Madbaygi (1992), at the Food and Agriculture Organization of the United Nations website (www.fao.org), at www.agri-jahad.org, the Iranian ministry concerned with fisheries, at the Caspian Environment Programme (CEP), Baku, Azerbaijan at www.caspianenvironment.org and in various articles such as Matinfar and Nikouyan (1995), Nash (1997a, 1997b), Mehrabi (2002), Sadeghi and Agheli (2002), Saeedi (2002), Falahatkar and Nasrollazadeh (2011), Kalbassi *et al*. (2013), Samadi Mirarkalaei and Samadi Mirarkalaei (2015), Allahyari (2016), Innovation Norway (2016), Matinfar (2016), Aquaculture in Iran, www.innovasjonnorge.no, downloaded 8 August 2018), Harlioglu and Farhadi (2017) and Alam (No date). Additional information is found under each of the **Species Accounts**.

Fisheries data from various sources (and sometimes the same source) are not always compatible or comparable. The data should be treated as indicative of trends and relative fishing pressure between species. Some years may have been inadequately reported, data is incomplete, sources for figures are disparate, poaching levels have varied, and low numbers may not reflect

actual catches.

Early accounts of fisheries along the Caspian shore of Iran were given by Nedoshivin and Iljin (1927, 1929), Vladykov (1964) and Keddie (1971). The bony fish catch in the Caspian Sea was about 8,000 mt in 1927-1935, declined to less than 500 mt in 1961-1964, increasing to 5,000 mt in 1965-1978 and falling to less than 1,000 mt in 1979-1981. Since 1981 the catch increased to 10,000 mt and has reached 24,000 mt. Among cyprinoids, *Rutilus frisii* has dominated since 1956 through artificial reproduction (Fazli, 2014). The freshwater fish catch increased from 6,954 tonnes/year in 1974-1976 to 24,613 tonnes/year in 1984-1986, a 254% increase and five times the world average (Gleick, 1993). Inland fisheries finfish production was 30,924 tonnes in 1986 and in 1992 Iran had an inland capture fishery of 40,000 t, as did Turkmenistan; Kazakhstan had 80,000 t, Uzbekistan 27,439 t, Azerbaijan 36,371 t, Iraq 4,400 t, and Armenia 4,500 t (Food and Agriculture Organization, Rome, Inland Water Resources and Aquaculture Service, Fishery Resources Division, 1995a). The Caspian Sea fisheries grew from 25,987 t to 98,000 t in the decade 1990-2000 (www.agri-jahad.org, downloaded 3 November 2003). Saheli (1999) gave figures that showed total aquatic production was dominated by Persian Gulf and Sea of Oman fisheries in 1995 at 63%, the Caspian Sea occupied 15% and inland waters 15%, the remainder being from international waters. Petr and Marmulla (2002) gave an average catch of 30,000 t for 1995-1999 in inland waters. Kilka (*Clupeonella* spp., Clupeidae) was the most important factor for increased catches in the Caspian and aquaculture in inland fisheries. The catch in 1998 was 75,000 t for inland waters (*Islamic Republic News Agency*, 15 June 1999) - catch records varied between sources but gave a general idea of the importance of freshwater fisheries. The value of all fish production in Iran rose to 1,046 billion rials in 1996 from 171 billion rials in 1989 (*Tehran Times*, 27 July 1998). Freshwater landings increased from 22,177 t in 1985 to 115,000 t in 1994 (Food and Agriculture Organization, Fisheries Department, 1996). Cold and warmwater fish production was 67,000 t in 2001 with per capita annual consumption at 5.2 kg. Production was expected to rise to 220,000 t in 2000-2005 (*Islamic Republic News Agency*, 11 November 2001) and per capita consumption to 18 kg by 2025 (Innovation Norway, 2016, Aquaculture in Iran, www.innovasjonnorge.no, downloaded 8 August 2018). Per capita yields for inland capture fisheries in kilogrammes after Food and Agriculture Organization, Rome, Inland Water Resources and Aquaculture Service, Fishery Resources Division (1995a) was as follows and showed marked increases over these years:-

| 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|
| 0.321 | 0.329 | 0.342 | 0.444 | 1.038 | 0.667 |

These values compare with neighbouring countries as follows for the same period:- Iraq (range 0.182-0.672), Turkey (0.666-0.903), Afghanistan (0.079-0.102) and Pakistan (0.773-0.874). Per capita supply of cultured fish was 1.3 kg in 2003 while capture fisheries yielded 5.1 kg (Food and Agriculture Organization, Fisheries Department, 2006). This same publication gave fish consumption in kilogrammes per capita as follows:-

| 1969-1971 | 1979-1981 | 1990-1992 | 1995-1997 | 2000-2002 |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 0.7 | 1.5 | 4.4 | 4.7 | 4.7 |

Catches in the Caspian Sea for 1991 and 1992 were 3,036 t and 2,692 t of sturgeons respectively, 13,817 and 21,527 t of kilka (*Clupeonella* spp., Clupeidae), and 18,571 and 16,873 t of bony fishes (which includes cyprinoids). The clupeid catch reached 51,000 t in 1994 from none 10 years previously (Food and Agriculture Organization (FAO), Fisheries Department, 1996). The FAO also recorded that the silver carp catch went from none in 1989 to 24,720 t in 1994. In inland waters the catches of warmwater fish went from 19,947 t to 21,462 t, of coldwater fish from 579 t to 775 t (both presumably from fish farming) and from natural resources from 24,905 t to 20,183 t. These catches (totals 80,855 t and 83,512 t) are less than the totals for the marine catches in the Persian Gulf and Sea of Oman at 277,000 t and 271,000 t but are still significant (*Abzeeyan*, Tehran, 5(9):III, 1995).

In 1996, the total Caspian Sea catch was 58,000 t while the southern, marine fisheries reached 265,000 t. The gross value of all catches (1995) including marine fish and shrimps was U.S. $45 million while fish imports were at $65 million. Caviar made up nearly 60% of exports in 1994 and nearly half of imports were fish meal. The industry had 111,800 primary employees in 1995, including about 8,000 fish farmers. Most fish (70%) were eaten fresh, 15% was frozen and canned, with some smoked or salted and the remainder was made into fish meal (Food and Agriculture Organization, Fishery Country Profile, 1997, at www.fao.org/waicent/faoinfo/fishery/fcp/irane.htm). There were 47 fish meal factories in Iran but demand was high for aquaculture and caused a 470% increase in price of farmed fish (Adeli and Baghaei, 2016). In 1998, the annual fish catch was listed as 65,000 t with the aim of raising the catch to 110,000 t by the end of the 1995-1999 economic development plan. It was estimated that 150,000 t could be obtained from 500,000 ha of ponds and dam reservoirs (*Islamic Republic News Agency*, 23 October 1998).

TACIS (2002) demonstrated the growth in catches in the Caspian Sea basin of Iran as follows. The kilka (*Clupeonella* spp., Clupeidae) catch was 2,000 tonnes per year in 1932-1959, 63,300 t/y in 1996-1998, mullets 390 t/y growing to 4,560 t/y, and total catch 7,440 t/y to 81,360 t/y. Nezami *et al*. (2000) gave the following figures for fish harvested from Caspian coastal provinces in Iran:-

Golestan:-

| Species/Year | 1997-98 | 1998-99 |
|---|---|---|
| *Rutilus frisii* (= *R. kutum*) | 174,869 kg | 191,680 kg |
| *Rutilus rutilus (= R. lacustris)* | 20,124 kg | 18.025 kg |
| Mugilidae | 43,016 kg | 229,487 kg |
| *Cyprinus carpio* | 229,734 kg | 260,890 kg |
| Other | 2,712 kg | 10,529 kg |

| | | |
|---|---|---|
| Total | 470,455 kg | 710,611 kg |

Mazandaran (1998):-

| Species | tonnes |
|---|---|
| Cultured fishes | 12,363 |
| *Rutilus frisii* (= *R. kutum*) | 2,174 |
| Mugilidae | 1,533 |
| *Clupeonella* (kilka) | 31,583 |
| Other bony fishes | 374 |
| Total | 48,027 |

Gilan (1997):-

| Species | tonnes |
|---|---|
| *Clupeonella* (kilka) | 36,077 |
| All bony fishes | 2,813 |
| Acipenseridae (sturgeons) | 264 |
| Total | 39,154 |

Unauthorised fishing in Gorgan Bay in the southeastern Caspian was estimated at 167,681 kg in 2000-2001 (Kamran, 2006). Mullets (*Liza aurata* and *L. saliens*) comprised 35.7% of the catch.

The biomass of fishes in the Iranian Caspian was estimated at 556,530 t, 12.7% of the total for the sea, with a fish density of 50.6 tonnes/nautical mile (the lowest values of any Caspian state) (Ivanov and Katunin, 2001). The Caspian Environment Programme (1998) gave the following tables for bony fish production in the Iranian Caspian Sea (tonnes) over 24 years:-

| Year/ Species | Kilka (*Clupeonella* spp.) | *Rutilus frisii* (= *R. kutum*) | Mugilidae | *Salmo trutta* (= *S. caspius*) | *Cyprinus carpio* | *Sander lucioperca* | *Abramis brama* | **Rutilus rutilus* | *Alosa pontica* (= *A. kessleri*) | *Silurus glanis* | Others | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1973 | 1,013 | 2.63 | 927.3 | 2.9 | 93.5 | 2.2 | 0.3 | 22.5 | 2 | 6 | 19.2 | 2,091.53 |
| 1974 | 1,170 | 338.6 | 403.5 | 1.3 | 101.6 | 2.8 | - | 34.6 | 2 | 10 | 20.6 | 2085 |
| 1975 | 1,286 | 695.7 | 963.4 | 1.4 | 84.4 | 9 | 0.3 | 29.5 | 4.5 | 6.5 | 27.8 | 3,108.5 |
| 1976 | 900 | 1,231.8 | 2,004.6 | 1.1 | 47.4 | 6.8 | 2.4 | 94.8 | 5.5 | 5.5 | 33 | 4,332.9 |
| 1977 | 1,261 | 530.6 | 1,297.9 | 1.5 | 40.1 | 11.2 | 1 | 18.6 | 2 | 5 | 36.5 | 3,205.4 |
| 1978 | 771 | 191.1 | 373.8 | 0.7 | 13 | 2.8 | 0.06 | 3.6 | - | 2.5 | 9.8 | 1,368.36 |
| 1979 | 836 | 84.1 | 352.4 | 0.6 | 69.6 | 0.4 | - | 11.9 | - | 0.1 | 2.6 | 1,357.7 |
| 1980 | 619 | 158.2 | 1,411.7 | 0.3 | 69.6 | - | - | 71.2 | 0.1 | - | 3.5 | 2,333.6 |
| 1981 | 1,341 | 252.1 | 408.3 | 0.4 | 129 | 1.6 | - | 217.4 | 0.4 | 2.5 | 9.7 | 2,362.4 |
| 1982 | 798 | 342.3 | 2,674.7 | 1.1 | 128.4 | 13.5 | - | 915.5 | 10.4 | 3.5 | 15.7 | 4,903.1 |
| 1983 | 621 | 277.9 | 1,637.7 | 0.7 | 160.2 | 4.1 | - | 108.6 | 1.6 | 3.5 | 16.7 | 2,832 |
| 1984 | 1,517 | 252.3 | 1,219.5 | 1.2 | 173.4 | 3.5 | - | 384.4 | 20.3 | 3.5 | 17.2 | 3,592.3 |
| 1985 | 1,828 | 174.5 | 1,402.9 | 1.1 | 16.4 | 0.7 | - | 200.5 | 34.8 | 3.5 | 10 | 3,672.4 |
| 1986 | 2,450 | 110.4 | 177.2 | 0.7 | 3.4 | 0.16 | - | 27.4 | 71.9 | 3.5 | 1.7 | 2,846.36 |
| 1987 | 4,389 | 162.7 | 109 | 0.5 | 19.5 | 0.2 | - | 6 | 13 | 3.8 | 10.5 | 4,714.2 |
| 1988 | 4,700 | 5,000 | 1,750 | 0.5 | 20 | 5 | 0 | 100 | 16 | 3.5 | 105 | 11,700 |
| 1989 | 7,902 | 6,500 | 2,380 | - | - | 5 | - | 130 | 30 | - | 2,068 | 015 |
| 1990 | 8,814 | 8,500 | 1,503 | 110 | - | 10 | - | 100 | 30 | 1,000 | 3,671 | 23,738 |
| 1991 | 13,817 | 12,000 | 2,500 | 130 | - | 100 | - | 120 | 35 | 1,000 | 2,686 | 32,388 |
| 1992 | 21,527 | 12,000 | 2,200 | 130 | - | 100 | 20 | 120 | 35 | 1,000 | 1,445 | 38,577 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | 28,730 | 12,727 | 5,135 | 1 | - | 16 | 17 | 714 | 893 | 670 | 2,155 | 51,058 |
| 1994 | 51,000 | 9,277 | 2,809 | 1 | - | 95 | 29 | 1,366 | 720 | 28 | 2,475 | 67,800 |
| 1995 | 41,000 | 8,435 | 5,014 | 13 | - | 10 | 5 | 1,178 | 490 | 5 | 650 | 56,800 |
| 1996 | 57,000 | 9,222 | 2,554 | 8 | - | 6 | 3 | 878 | 330 | 22 | 2,477 | 72,500 |

*May include *R. caspicus* (= *R. lacustris*) as these taxa were not distinguished.

Abdolmalaki and Psuty (2007) gave figures over a wide range of years for Iranian coastal catches in the southern Caspian Sea as follows:-

| Catch and frequency | 1927-1936 | 1937-1946 | 1947-1956 | 1957-1966 | 1967-1976 | 1977-1986 | 1987-1996 | 1997-2003 |
|---|---|---|---|---|---|---|---|---|
| Total recorded catch (t) | 8,959 | 7,224 | 4,986 | 3,262 | 5,547 | 5,384 | 16,903 | 16,201 |
| *Sander lucioperca* (%) | 29.7 | 1.7 | 1.0 | 0.2 | 0.4 | 0.1 | 0.1 | 0.2 |
| Sturgeon meat + caviar (%) | 13.4 | 8.8 | 16.3 | 50.9 | 40.9 | 34.2 | 9.4 | 5.0 |
| *Cyprinus carpio* (%) | 9.8 | 8.5 | 1.8 | 2.5 | 2.6 | 1.1 | 6.3 | 6.1 |
| *Rutilus frisii* (= *R. kutum*) (%) | 12.2 | 43.0 | 24.9 | 25.8 | 17.8 | 19.8 | 53.2 | 45.4 |
| *Rutilus rutilus* (= *R. lacustris*) (%) | 20.7 | 25.5 | 18.8 | 0.7 | 0.8 | 2.3 | 5.8 | 6.1 |
| *Alosa* spp. (%) | 1.9 | 6.2 | 14.7 | 2.9 | 0.3 | 0.2 | 3.2 | 3.9 |
| *Liza aurata* and *L. saliens* (%) | 0 | 1.8 | 20.9 | 15.8 | 36.1 | 42.2 | 19.7 | 28.9 |
| Other species (%) | 12.3 | 4.5 | 1.6 | 1.2 | 1.1 | 0.2 | 2.5 | 4.4 |

The bony fish catches in the Iranian Caspian Sea waters for 1999-2000 were given by D. Ghaninejad (5th International Symposium on Sturgeon, Iranian Fisheries Research Organization, 9-13 May 2005, Ramsar). Beach seine cooperatives took 11,170 t and the total catch, allowing for poaching, was estimated at 16,860 t. The total kutum (*Rutilus frisii* (= *R. kutum*)) catch was 1,400 t and this species had an estimated biomass in Iranian waters of about 22,000 t. The catch of *Liza aurata* (= *Chelon auratus*, golden mullet) was estimated at 3,559 t with about 22% undersized and the biomass estimated at 11,100 t. *Cyprinus carpio* biomass was very low and was estimated at 4,200 t. The *Rutilus rutilus* (= *R. lacustris*) catch was estimated at 1,340 t for 2000-2001, mostly poached with gill nets, and *Sander lucioperca* (pike-perch) at 18 t for the same period, mostly undersized and immature. The total catch of *Abramis brama* was estimated to be 17 t, again undersized and immature.

Catches in the Caspian Sea showed no differences between seven regions based on catch-per-unit-effort (cpue) (Mirzajani *et al*., 2005). Catches varied from 88 to 459 kg/cpue for 1991-92 and 31-418 kg/cpue for 1994-95. In 2000-01, the Anzali region had the highest values, significantly different from the Astara-Hashtpar and east of Gilan province regions.

Beach seines are known as *pareh* in Farsi, usually referring to a seine without a cod-end. Beach seine cooperatives increased from 68 in 1989 to 151 in 2004 while the numbers of fishers doubled from 6,000 to 12,000. About 85-100 people are members of each beach seine cooperative. The beach seines are 1,000-1,200 m long, some with a cod-end 10-15 m wide and 100 m long and with a mesh size legally fixed at 30 mm (smaller meshes are used too). They are hauled in by tractors. Although there are minimum sizes for fish retention, fisheries do retain smaller ones for home consumption or even marketing (Abdolmalaki and Psuty, 2007). Ghorbani *et al*. (2010) surveyed fish catches in beach seine cooperatives in Golestan Province in 2005-2006, species caught varying with zones and their bottom composition and hence available prey items. Paighambari *et al*. (2013) also looked at Golestan catches by beach seines noting a catch of 462,680 kg from 1,534 hauls. *Rutilus caspicus* (= *R. lacustris*) had the lowest part of the teleost catch and 49.4% of kutum and 73.7% of common carp were larger than fishing standard size. Zarei Yam *et al*. (2015) examined the quality of salted dried fish sold in Golestan from shore markets (species not specified), finding production and sale conditions were poor. Taghavi Motlagh *et al*. (2011a, 2011b) compared beach seine height and mesh size on fish catches in the Caspian Sea, with a 20 m seine height catching more than a 24 m seine and 33 mm mesh catching more *Rutilus kutum* and less *Liza aurata* (= *Chelon auratus*, golden mullet) than a 30 mm mesh. Yazdani *et al*. (2017) and Riahi and Yazdani (2018) analysed the economics and technical efficiency of *pareh* or beach seine cooperatives in Mazandaran over the 2014 fishing season. Only two of 12 cooperatives had technical and economical efficiency.

Salehi (2008c) summarised the Iranian Caspian fisheries for <u>bony</u> fishes. In 2006 the industry employed more than 10,000 fishermen with 142 co-operatives managing the industry. Average yearly production was over 18,000 t for 1980-2006. Landings of *Rutilus kutum* were estimated to average 46.6% of the total bony fish catch from 1983 to 2006 due to the stock enhancement project for this species. Average fingerling production of this species from 1981 to 2006 was 191,776,000 fish (17,536,000 for sturgeon, 18,024,000 for *Abramis brama* and 11,012,000 for *Rutilus rutilus* (= *R. lacustris*)). Beach seines were back in use as the gill nets of the 1980s were found to adversely affect sturgeon stocks. Each net may require up to 100 people and a tractor to operate. Re-introduction of beach seines partly accounts for catches rising from 17,629 t in 1993 to 21,845 t in 2005 and 23,802 t in 2006. Ghaninezhad and Abd Almalaki (2009) gave further details on bony fish exploitation in the Caspian Sea and Alyan (2010) commented on declines in the fishery. Fazli *et al*. (2017) analysed time series encompassing the years 1950-2011 for commercial fish landings from the Caspian Sea. Cyprinoids studied included *Abramis brama*, *Cyprinus carpio*, *Rutilus kutum* and *R. lacustris*. Explanatory variables were sea level and Volga River water volume, and landings were highly correlated with environmental variables. The two most important trends in the response variables were a decrease in landings during the second half of the time-series and a fluctuating pattern.

The whole fisheries industry, including the Persian Gulf marine fin fisheries and shellfish, received an investment of 500 billion rials by the government and 800 billion rials by the private sector, apparently for the period 1989-1993. Nine billion rials were allocated to aquaculture by the government in 1993, planned to rise to 23 billion rials in 1994, and to 210 billion rials in the next five-year economic development plan. In 1995, 200 billion rials were

allocated to preparation and provision of infrastructure activities for fish farming (http://netiran.com/news/IranNews/html/9503131INEC.html). A national project to expand fish farming within a six-year period would raise annual production by 50,000 t, create 30,000 jobs, earn $50 million a year and increase consumption of fish to 10 kg per person (*Islamic Republic News Agency*, 22 January 2000). Consumption of fish in Iran is estimated at 5 kg per capita, having risen from 1 kg in the decade prior to 1999 and is expected to rise to 6.5 kg in the next five-year economic plan (by the year 2000) and to 10 kg by 2004 (later revised to 8.5 kg by 2005 (*Islamic Republic News Agency*, 25 September 2000)). Per capita consumption of fish increased due to increased production but also a government policy of lower prices than for meat and poultry (*Islamic Republic News Agency*, 6 March 1999; 31 May 1999). In 1993, 350,000 t of seafood products were produced comprising 30% of the country's protein requirements and a sevenfold increase over catches before the Islamic Revolution in 1979 (*Abzeeyan*, Tehran, 4(9):VI, 1993). The annual fisheries output was expected to reach 1 million tons by the year 2004 from a 1999 level of 400,000 tons (*Islamic Republic News Agency*, 6 March 1999). Fish exports were expected to earn Iran $400 million and create 150,000 jobs by 2004. The 1999-2000 government budget allocated 300 billion rials to fisheries (*Islamic Republic News Agency*, 6 March 1999). In 1998, Rana and Bartley (1998) reported the average per capita fish consumption in Iran to be 4.5 kg, low compared to the world average of 13.5 kg. The Government's plan was to increase consumption to 6.5 kg by the year 2020 which would require an increase in fishery production from 382,000 t in 1995 to 670,000 t; these amounts conflicting with news reports. Adeli *et al*. (2020) identified factors affecting fish exports.

Aquaculture has a high priority in Iran and expanded at 8.2% per year during 1990-1996, the value in 1996 being U.S. $306.6 million for a production of 30,000 t. However, aquaculture production for 1988 was only exceeded in 1995 (www.fao.org/fi/publ/circular/c886.1/wasia3.asp). Mahboobi and Hasanabadi (2014) investigated barriers to warmwater fish culture in Golestan Province finding a lack of sufficient number of extension education classes, lack of funds and governmental support, loss of subsidies, increase in fuel prices, failure to observe hygiene by staff, algal blooms, lack of behavioural risk character vulnerability in aquaculturists and lack of chemical fertilisers. Yelghi *et al*. (2015) found the highest cost gradients per kg of fish in Golestan in 2009 were juvenile preparation, rent and labour salaries. The mean net benefit in Golestan was 28,034,000 rials and Gonbad had the highest benefit/ha at 32,368,200 rials. Yelghi *et al*. (2015) evaluated the economics for 39 Golestan aquaculture sites in 2010 finding the lowest cost and highest benefit per hectare in facilities up to 25 ha. Kamali Sanzighi and Mousavi Nadushan (2015) evaluated zooplankton communities and the saprobic index for six Chinese carp (including *Cyprinus carpio*) ponds at Gonbad-e Kavus, Golestan. Kavoosi Kalashami *et al*. (2016) evaluated production characteristics and cost structure of warmwater farms in Guilan by random sampling of aquaculture units in Rasht. The average total factor productivity was 81% and the average technical efficiency was 84% to 92% depending on methodology. Also, more than 50% of units had more than 90% efficiency showing a good situation for warmwater aquaculture units in this district.

Over 975 million fingerlings were released into the Caspian Sea and inland waters from hatcheries or given to fish farmers to be cultured in ponds during the first five-year plan, 1989-1993. During the next five-year economic plan, the catch was expected to increase to 2.6 million t from 1.309 million t and 1.9 billion fingerlings would be released (*Abzeeyan*, Tehran, 4(9):V, 1993). The Iranian Fisheries Research and Training Organization was expected to have a budget

of 35 billion rials by the end of 1993, indicative of the importance attached to developing fisheries in Iran (*Abzeeyan*, Tehran, 4(5):IV, VII, 1993).

Prior to the Islamic Revolution in 1979, the Iranian fisheries were divided into two companies, known as Shilat in Farsi, a northern one centred on the Caspian Sea and a southern one centred on the Persian Gulf. The combined companies, known as the Iranian Fisheries Organization or Shilat, were under the Jihad-e Sazandegi Ministry, starting in 1987. Jihad-e Sazandegi translates as Construction Crusade and is indicative of the attempt to develop the fisheries to serve the growing population of Iran. The Organisation is now known as Jihad-e Agriculture as of the year 2000. The Iranian Fisheries Research and Training Organization officially commenced its activities in 1990 and is now known as the Iranian Fisheries Research Organization. It has departments of Research, Training, Scientific Information and Administration and Research Centres at Bandar-e Anzali and Sari in the north of Iran and at Bushehr, Bandar-e Abbas, Ahvaz, Bandar-e Lengeh and Chahbahar in the south. A general account of the fisheries and their organization in Iran was given at http://netiran.com/press/economy-domestic/html/000000XXDE0090.html which was available on the net on 14 April 1997 and a more recent version was at www.netiran.com/php/artp.php?id=1609, downloaded 19 July 2004.

Aquaculture is now of major significance. Danesh-e-Khoshashi (1998) described facilities and methods used for spawning Chinese carps in Gilan Province. The production of Chinese carp fingerlings has been relinquished to the private sector in Iran. The silver carp catch increased from none in 1989 to 24,720 t in 1994 (Food and Agriculture Organization, Fisheries Department, 1996). Chinese carp production peaked in 2006 at more than 77,000 t according to Salehi (2009) who also reviewed carp farming costs. Chinese carp fingerling production was 22.7 million in 1996 (Bartley and Rana, 1998a). Stakei (1999) studied nutrients, BOD (biological oxygen demand) and COD (chemical oxygen demand) in manured polyculture ponds with Chinese carps in Iran. A review of world cyprinoid culture, with special reference to the Chinese carps, was given by Billard (1995).

There are about 3,000 fish farms producing over 98% of the cultured fish in the country. Yearly production of all cultured fish has increased from 4,753 tonnes in 1985 to 45,134 t in 1990. Production of carps in government hatcheries has risen as follows:- 2.19 million fingerlings in 1983, 5.04 million in 1984, 12.84 million in 1985, 20.83 million in 1986, 19.05 million in 1987, 50.00 million in 1988, 50.80 million in 1989, 97.70 million in 1990, 58.00 million in 1991, and 50.00 million in 1992. In addition, private sector production probably equals these figures (Emadi, 1993a). Polyculture of common, bighead and silver carp has been tried in Iran (Kamaly, 1991). Fish were stocked in four 200 sq m ponds at three densities in polyculture (2,700, 3,750 and 4,750 by species) and at one density in monoculture (9,500) fish per hectare. Bighead and silver carp attained a mean weight of 526 and 498 g in polyculture and common carp averaged 343, 190 and 100 g in the same culture but only 13.6 g in monoculture. The growth rate in summer averaged 94.4, 93.7 and 76.1% for silver, bighead and common carp in polyculture and 71.9% for common carp in monoculture. Pen culture in the Caspian Sea has been investigated for *Cyprinus carpio* and the various Chinese carps (*Iranian Fisheries Research and Training Organization Annual Report, Tehran*, 1992-93). Semi-artificial breeding of grass, silver and bighead carps has been carried out in Iran (*Iranian Fisheries Research and Training Organization Newsletter*, 6:3-4, 1994; *Annual Report*, 1994-1995, *Iranian Fisheries Research and Training Organization*, *Tehran*, p. 39, 1996). Hormone injections were used to induce breeding of fish held in a round trough for spawning with a rectangular egg collection trough and

a round egg hatching trough. Spawning occurred within 6.5-12.5 hours of injection. The percentage of hatched larvae in this semi-artificial method was higher than a control artificial method where eggs were kept in incubators. The increase was 6% for grass carp, 33.72% for silver carp and 16.7% for bighead. Active larvae increased from 180,000 to 450-500,000 for grass carp, from 157,000 to 400-450,000 for silver carp and from 680,000 to 970,000 for bighead carp. Additionally, female breeder mortality was 3.37% less for grass carp and 45.19% less for silver carp.

Rana and Bartley (1998a) gave details of carp aquaculture in Iran. They noted that silver carp production increased 11% per year between 1991 and 1996 and bighead carp 7%. Most carp production occurs in the provinces of Gilan, Mazandaran and Khuzestan as a private sector enterprise. Carp broodstock is selected based on head size, colour and gill structure (surface and shape). Adults are replaced after 3-4 years. Circular concrete tanks are used for spawning and have egg collecting and incubation devices, which reduce handling to the minimum. The young carp are grown to market size in ponds or complex fish farms. In 1994, there were 2,583 registered farms with a water surface area of about 8,000 ha. Organic and inorganic fertilisers are used along with supplementary foods. Fertilisers include urea (135-1,500 kg/ha/yr), ammonium phosphate (80-575 kg/ha/yr) and manure (3-10 tonnes/ha/yr). Supplementary diets include a variety of grains (100-6,000 kg/ha/yr) or, for intensive monoculture of common carp, high protein pellets (30-40%). Fingerlings are stocked in March-April at a density of 2,000-6,000 per hectare and sold between November and February. Production is 1.6-5.5 tonnes/ha.

Cultivated carps are susceptible to fungal infections as detailed by Ebrahimzadeh Mousavi *et al*. (2000) for the Sefid River Fish Farm Centre where 31 species of fungi were isolated and Firouzbakhsh *et al*. (2005) where 39 fungal species were identified from gill lesions in common, silver and grass carp on five fish farms in Mazandaran.

Rice fields in Iran are now being used for fish culture. Some papers refer to "rice-fish" but this means fish farmed in rice fields, mostly cyprinoids, not the rice fish (*Oryzias latipes*, Adrianichthyide) and its relatives. Experimental production of 300-500 kg per hectare of carp "seed" (presumably young fish) and 750-1,000 kg of fish and ducks in the autumn after the paddy is harvested (*Iranian Fisheries Research Organization Newsletter*, 22:2, 2000). In the early 1970s, intensive carp culture yielded only half the profits of rice culture (Carl Bond archives, Oregon State University, Corvallis). Literature on rice-fish culture in Iran includes Karami *et al*. (2006), Amiri and Nahvi (2012), Noorhosseini-Niyaki and Allahyari (2012), Noorhosseini-Niyaki and Bagherzadeh-Lakani (2013), Taleshi *et al*. (2013), Noorhosseini *et al*. (2014), Ebrahimi *et al*. (2015), Haghdoust *et al*. (2015), Keshavarz-Shal and Noorhosseini (2015) and Motamed *et al*. (2017). The fish involved are Chinese major carps, which aid growth of rice by addition of nutrients to the fields, reducing the need for fertilisers, pesticides and herbicides, increasing the quality of rural food and providing additional income to farmers from the sale of fish. Rice-fish culture occurs in Fars, Gilan, Lorestan and other well-watered provinces. Gilan produced 493 tons of fish from rice fields in 2011 (Innovation Norway, 2016, Aquaculture in Iran, www.innovasjonnorge.no, downloaded 8 August 2018).

Aquaculture increased in Iran from 5,000 tons in 1978 to 125,000 tons in 2005 and was 39% of fishery production in 2014. Warmwater aquaculture was 60-70% silver carp, 15-20% common carp and 5-12% each for bighead and grass carp. Warmwater aquaculture of Chinese carps was 63.5% of aquaculture (*Oncorhynchus mykiss*, rainbow trout) and shrimps being the other major cultured organisms). Projected aquaculture should yield 974,000 metric tonnes in 2025 with 605,000 mt through catches (Innovation Norway, 2016, Aquaculture in Iran,

www.innovasjonnorge.no, downloaded 8 August 2018). Demand for fishery products is expected to outstrip that available from fisheries (Salehi, 2003). Iran is a major producer of Chinese carps (Billard and Berni, 2004). For the year 1986-1987 aquaculture production was the largest in Southwest Asia and in 1992 at 42,420 t, it represented 50% of the production for West Asia and by value it was 62% (Food and Agriculture Organization, Rome, Inland Water Resources and Aquaculture Service, Fishery Resources Division, 1995b). Yearly cultured fish production climbed from 4,753 t in 1985, to 15,000 t in 1986, 18,000 t in 1987, 33,684 t in 1988, 39,913 t in 1989, and to 45,134 t in 1990. In 1995, Iran had 32% of the main aquaculture production in West Asia (among Turkey, Israel, Iraq and Syria) although it had been 47% in 1984. The decline was due to a slower growth rate. The 1995 production was 29,000 t (Shehadeh, 1997). However, other sources differ with a freshwater aquaculture production of 13,615 t for 1995 according to the Food and Agriculture Organization, Rome, Fisheries Department and Network of Aquaculture Centres in Asia-Pacific Bangkok (1997). This source summarised action plans and national objectives for aquaculture. The year 2005-2006 had 96,000 tons of warm and 32,000 tons of coldwater production (*Iran Daily*, 10 May 2006).

The Food and Agriculture Organization, Rome, Inland Water Resources and Aquaculture Service, Fishery Resources Division (1995b) also gave different figures for a range of years:-

| Year | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|
| tonnes (t) | 18,369 | 17,776 | 20,930 | 24,820 | 28,900 | 31,000 | 45,134 | 20,226 | 42,420 |
| $ U.S. x 1,000 | 36,988 | 62,217 | 94,650 | 164,201 | 251,500 | 299,000 | 446,876 | 208,298 | 424,534 |
| % West Asia t | 47.72 | 44.58 | 48.54 | 50.80 | 50.15 | 50.87 | 57.76 | 35.84 | 50.30 |
| % West Asia $ | 33.23 | 44.54 | 51.26 | 63.47 | 63.40 | 66.32 | 71.23 | 49.33 | 62.04 |

The Caspian Environment Programme (1998) gave annual production (in thousands) of the main cultured fish species in government and private hatcheries as follows:-

| Year/Species | *Rutilus frisii* (= *R. kutum*) | Acipenseridae | *Cyprinus carpio* | *Salmo trutta* (= *S. caspius*) | *Oncorhynchus mykiss* | *Abramis brama* | *Sander lucioperca* | Total |
|---|---|---|---|---|---|---|---|---|
| 1978 | 11,857.4 | 3,244.8 | - | - | - | - | - | 15,102.2 |
| 1979 | 2,637.8 | 2,911.4 | - | - | - | - | - | 5,549.2 |
| 1980 | - | - | 3,003.5 | - | - | - | - | 3,003.5 |
| 1981 | 405 | 2,044 | 5 | - | - | - | - | 2,454 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1982 | 280 | 1,016.2 | 811.7 | - | - | - | - | 4,637.1(*sic*)[1] |
| 1983 | - | 25,335.3 | 1,028.9 | 2,185.8 | - | - | - | 28,550.2(*sic*)* |
| 1984 | 28,342.2 | 1,104.7 | 5,036.5 | - | 570 | - | - | 35,053.5(*sic*)* |
| 1985 | 38,000 | 1,132.1 | 12,836.1 | - | 1,804.5 | - | - | 53,772.8(*sic*)* |
| 1986 | 51,704.9 | 2,283.6 | 20,831 | - | 1,565.2 | - | - | 76,384.8(*sic*)* |
| 1987 | 72,000 | 3,040 | 19,044 | - | 3,012 | - | - | 97,096 |
| 1988 | 84,306.7 | 3,157.5 | 50,021.9 | 50 | 50 | - | - | 138,036.3(*sic*)[2] |
| 1989 | 140,158 | 3,149 | 61,176 | - | 7,280 | - | - | 211,763 |
| 1990 | 156,268 | 4,343 | 93,377 | 155 | 5,389 | 66 | 118 | 259,716 |
| 1991 | 109,843 | 6,608 | 84,208 | 155 | 4,979 | 2,275 | 1,630 | 209,693(*sic*)* |
| 1992 | 144,680 | 3,457 | 42,709 | 360 | 1,834 | 5,929 | 2,443 | 200,782(*sic*)[3] |
| 1993 | 100,047 | 4,176 | 73,321 | 335 | 7,401 | 5,524 | 1,160 | 191,964 |
| 1994 | 142,734 | 6,295 | 104,089 | 640 | 8,423 | 10,350 | 2,888 | 275,418(*sic*)* |
| 1995 | 117,919 | 9,125 | 112,824 | 800 | 11,937 | 11,217 | 2,270 | 266,092 |
| 1996 | 142,092 | 12,456 | 130,371 | 424 | 28,940 | 8,478 | 2,414 | 325,175 |

*Total from Caspian Environment Programme (1998), not quite accurate; [1] = 2,107.9; [2] = 137,586; [3] = 201,412.

Aquaculture production was expected to reach 110,000 t by 1999 (*Abzeeyan*, Tehran, 6(8):V, 1995) although reports in 2001 listed a figure of 90,000 t. The production target for 2006 was 550,000 t, an increase of 1,800% over 1995 (Shehadeh, 1997). These figures conflict with the ones in the table above*. The following table from www.agri-jahad.org, downloaded 15 November 2002 gave somewhat different figures for production of aquatic farms but it is not always clear whether the same values and methods of organising data are being used:-

| Description/Year | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| Number of Farms | 3,330 | 3,647 | 3,801 | 4,524 | - |
| Area (ha) | 558,151 | 516,268 | 741,592 | 819,052 | - |

| | | | | | |
|---|---|---|---|---|---|
| Production (tonnes) | 65,000 | 65,000 | 72,000 | 67,800 | 66,000 |

Hosseinzadeh (2003) gave the following figures in tonnes for total fisheries production in Iran (note that southern waters are marine captures):-

| Year/Area | Caspian Sea | Southern Waters | Inland Waters | Total |
|---|---|---|---|---|
| 1978 | 3,724 | 25,500 | 3,219 | 32,443 |
| 1987 | 14,401 | 130,000 | 15,000 | 159,401 |
| 1989 | 21,193 | 239,000 | 40,490 | 300,683 |
| 1990 | 25,978 | 247,000 | 42.040 | 315,018 |
| 1991 | 34,596 | 248,000 | 45,131 | 327,727 |
| 1992 | 40,769 | 271,000 | 42,420 | 354,189 |
| 1993 | 52,768 | 272,000 | 44,123 | 368,891 |
| 1994 | 69,700 | 235,000 | 45,300 | 350,000 |
| 1995 | 58,300 | 265,000 | 59,000 | 382,300 |
| 1996 | 74,100 | 260,920 | 65,000 | 400,020 |
| 1997 | 76,200 | 259,000 | 65,000 | 400,200 |
| 1998 | 101,500 | 226,500 | 72,000 | 400,000 |
| 1999 | 110,000 | 234,200 | 67,800 | 412,000 |

Hosseinzadeh (2003) also gave warmwater fish (major carps, see below) production by province. Average production (tonnes/ha) increased as follows:- 1989 (1), 1990 (1.5), 1991 (1.5), 1992 (2.8), 1993 (3.0), 1994 (3.1), 1995 (3.3), 1996 (3.5), 1997 (3.4), 1998 (3.5) and 1999 (3.6). Total coldwater fish production (primarily *Oncorhynchus mykiss* (rainbow trout)) ranged from 546.5 t in 1990 to 7,032 t in 1999, for comparison.

The website www.iranseafoodexpo.ir/portion.asp, downloaded 9 February 2006, gave the following production of freshwater fishes, presumably in tonnes, with some obvious rounding of figures and conflicts with figures above:-

| Year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Coldwater | 835 | 1,200 | 1,500 | 1,900 | 2,510 | 4,994 | 7,000 | 9,000 | 12,170 | 16,026 | 23,137 |
| Warmwater | 43,288 | 44,728 | 51,554 | 63,229 | 61,964 | 66,137 | 55,862 | 52,987 | 53,843 | 79,084 | 67,811 |

Soltani and Ghaeni (2015) gave figures for production of Chinese carps in pond systems as 140,000 tons (presumably metric tonnes) in 2012 and 168,000 tons in 2014.

Carp culture is the most important fisheries subsector according to Salehi (1999, 2004a). Chinese major carps are reared in hatcheries and, at about eight days of age, they are transferred to nursery ponds. At about 10 g in weight they are transplanted into water bodies or grown out to market size (1 kg) in farm ponds (Saheli, 1999). Salehi's 1999 thesis gave an economic, marketing and consumer study of carp culture in Iran in the 1990s, concentrating on *Cyprinus carpio*. He mapped fish culture facilities and hatcheries, gave production of carps by species and by provinces, and also gave an overview of Caspian fisheries apart from carps. However, carp culture is more generally used in the sense of the Chinese major carps (*Cyprinus carpio*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella* and *Hypophthalmichthys nobilis*), often reared in polyculture (see Coad (2020)). These species are of similar nutritious value (Jorjani *et al*., 2013). Common, grass and silver carps have even been processed into fish fingers in Iran (*Iranian Fisheries Research Organization Newsletter*, 25:1, 2000). *C. idella* commanded the highest price followed by *H. molitrix* with *C. carpio* the cheapest. Polyculture stocking in natural and artificial water bodies was usually 28-32% *Cyprinus carpio*, 40-50% *Hypophthalmichthys molitrix*, 5-10% *H. nobilis* and the rest *Ctenopharyngodon idella*. Average yields varied from 43 kg/ha in 1993, to 40 kg/ha in 1994 to 49 kg/ha in 1995. Higher yields were cited by Salehi (2004a) at 1,540 kg/ha in 2001 but this may be for growth in summer months and special conditions. Total carp production was 54,000 t in 2001 (but see below after FAO, also from Salehi). Salehi's data differ from those of Hosseinzadeh (2003) above. The following figures are in tonnes:-

| Species/Year | 1991 | 1993 | 1995 | 1997 | 1999 | 2000 | % growth 1990-2000 |
|---|---|---|---|---|---|---|---|
| *Cyprinus carpio* | 5,502 | 4,206 | 6,561 | 5,435 | 4,600 | 7,000 | 27 |
| *Hypophthalmichthys nobilis* | 983 | 1,052 | 1,269 | 1,360 | 1,150 | 1,500 | 53 |
| *Hypophthalmichthys molitrix* | 10,019 | 12,619 | 15,228 | 16,310 | 13,800 | 17,000 | 70 |
| *Ctenopharyngodon idella* | 3,143 | 3,155 | 3,942 | 4,078 | 3,450 | 2,000 | -36 |
| Total | 19,647 | 21,032 | 27,000 | 27,138 | 23,000 | 27,500 | 40 |

*Cyprinus carpio* aquaculture production in tonnes by year was given by Harlioglu and Farhadi (2017) as follows:- 65,400 (2004), 73,396 (2005), 77,463 (2006), 97,262 (2007), 87,748 (2008), 100,430 (2009), 121,608 (2010), 132,177 (2011), 154,565 (2012), 167,883 (2013) and 170,341 (2014). The number and area (hectares) of cyprinoid fish farms in Iran were:-

6,084/25,891 (2004), 6,319/28,332 (2005), 6,863/29,836.7 (2006), 7,261/33,793 (2007), 7,923/31,892 (2008), 8,362/34,504 (2009), 10,527/40,261 (2010), 11,968/43,722 (2011), 14,295/46,587 (2012), 14,615/48,697 (2013) and 16,254/50,583 (2014).

Production by major fish-culturing provinces from Salehi (2004a) for carps was as follows:-

| Province/Year | 1991 | 1993 | 1995 | 1997 | 1999 | 2001 | % share in 1995 | % share in 2001 |
|---|---|---|---|---|---|---|---|---|
| Khuzestan | 9,119 | 6,019 | 2,830 | 12,000 | 4,309 | 200 | 11 | 0.8 |
| Gilan | 6,689 | 2,164 | 1,445 | 1,360 | 1,029 | 1,270 | 6 | 4.8 |
| Mazandaran and Golestan | 1,958 | 3,813 | 8,975 | 10,060 | 9,518 | 15,700 | 36 | 60.9 |
| Sistan and Baluchestan | 4,353 | 3,000 | 4,600 | 4,200 | 11,307 | 0 | 19 | 0 |
| Fars | 216 | 2,657 | 1,320 | 1,450 | 743 | 400 | 5 | 1.5 |
| West Azarbayjan | 875 | 1,065 | 1,633 | 1,800 | 1,905 | 2,350 | 7 | 9 |
| Others | 1,693 | 3,539 | 4,036 | 3,915 | 5,007 | 5,865 | 16 | 23 |
| Total | 24,903 | 22,257 | 24,836 | 34,785 | 33,818 | 25,785 | 100 | 100 |

Kalbassi *et al*. (2013) gave a figure of 134,100 t for aquaculture and inland fisheries in 2005 of which 73,396 t was from carp farming, comprising 63% silver carp, 25% common carp, 7% grass carp and 5% bighead carp. Cyprinoidei in aquaculture had production and value in 1995 and 2008 respectively of 27,000 t and 87,679 t and U.S. $71,439,000 and U.S. $232,349,000. Carp production in Iran ranked 13$^{th}$ in the world in 1980 and 8$^{th}$ in 2008. Native species with economic potential for aquaculture were listed as *Barbus* (= *Mesopotamichthys*) *sharpeyi*, *Barbus* (= *Arabibarbus*) *grypus* and *Abramis brama*. Vazirzadeh (2015) also mentioned these three species and added *Luciobarbus capito* and *L*. *xanthopterus* as having potential in Iranian aquaculture.

New aquaculture developments are reported regularly, e.g., see for earlier examples *Abzeeyan*, Tehran, 7(4):IV-VI, 1996; Aavakh-Kismi, 1996). Ramin (2015) surveyed suitable sites for carp aquaculture assessing ecological factors including physical and chemical factors, geological factors including topography and type of soil, biological factors including selection of species and control of invader animals, climatic factors, geographical factors, and pollutants including heavy metals, agricultural pesticides, surfactants and crude oils. Akram *et al*. (2017) questioned 57 fish farmers in a study to optimise energy consumption in production of warmwater fishes. Akram *et al*. (2019) investigated and predicted the amount of environmental

impact in breeding warmwater fish in Guilan Province using a comparative neuro-fuzzy inductive inference system. Aminian Fatideh and Pour Asadi (2019) integrated poultry with fish farming in Gilan. Five months of fish breeding, three duck periods and a goose period gave a total amount of product of 8,800 kg, 2.6 times the normal harvesting of fish in breeding ponds. Hosseinjani *et al*. (2019) described a small-scale (3 ha), warmwater aquaculture facility at Ijroud in Zanjan.

The share of aquaculture compared with total fisheries production more than doubled between 1980 and 1987, from 5.5% to 12% due to high private sector investment while the monetary value climbed from 10.9% to 22.2%. Aquaculture is concentrated in Gilan, Mazandaran, Khuzestan and Markazi or Tehran provinces where 96% of the total number of existing establishments are found and 87% of total production (Ahmadi, 1993). Various other areas of the country are taking on fish culture plans, e.g., Anonymous, 1991b; *Islamic Republic News Agency*, 29 July 2000) - Lorestan Province; Anonymous (1992b) - Chahar Mahall and Bakhtiari Province; Anonymous (1996a) - Kermanshah Province (and see Najafi *et al*. (2018)); and *Islamic Republic News Agency* (19 October 1997) - Ilam Province). In 1992 there were over 8,047 ha of ponds and 503,500 ha of natural and semi-natural reservoirs. Consumption of aquaculture products was 800 g and over 10,400 people were employed in private sector aquaculture (Emadi, 1993a). The number of warmwater fish farms in 1996 was 3,736 with an area of 7,989 ha and the number of coldwater fish farms was 79 with an area of 164,984 ha (*Iranian Fisheries Research and Training Organization Newsletter*, 17:4-5, 1997). Lorestan Province produced 772 t of farmed fish in 1997 with 1,000 t predicted for 1998 and a long-term goal of 21,000 t worth 156 billion rials and 10,000 jobs. In 1997, 50 fish farms were under construction along with 125 pools for fish culture purposes and 10 billion rials were invested (*Tehran Times*, 22 September 1998). The Azadegan Fish Farm south of Ahvaz was scheduled to produce 70,000 t of cold and warmwater fishes annually from 342 pools of 15 or 40 ha, employing 4,250 people directly and 13,000 indirectly, and with a gross revenue of 305 billion rials annually (*Islamic Republic News Agency*, 11 November 1998). In the Iranian year ending 20 March 2002, warmwater fish culture produced 3,843 t and coldwater culture 12,169 t (*Islamic Republic News Agency*, 6 November 2002). Confusingly, the warmwater fish production in the year ending 20 March 2003 was expected to be 30,000 t according to *Islamic Republic News Agency* (17 December 2002), and compare tables above.

The following table from www.agri-jahad.org, downloaded 15 November 2002 shows production of fry of various species in thousands:-

| Description/Year | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| Kutum | 142,092 | 154,367 | 143,361 | 147,879 | 147,437 |
| Sturgeons | 12,456 | 21,626 | 24,557 | 18,857 | 18,279 |
| Carps | 130,371 | 113,172 | 33,785 | 99,493 | 116,398 |
| Salmon | 424 | 349 | 510 | 412 | 400 |
| Trout | 28,940 | 28,651 | 75,378 | 71,930 | 115,166 |

| | | | | | |
|---|---|---|---|---|---|
| Bream | 8,478 | 12,995 | 13,792 | 14,231 | 14,325 |
| Perch (probably zander) | 2,414 | 3,800 | 3,615 | 4,257 | 3,931 |
| Other | - | 15,800 | 13,896 | 10,977 | 16,900 |
| Total | 325,175 | 350,760 | 308,894 | 368,036 | 432,836 |

Kutum, whitefish or white fish (*Rutilus kutum*) is very popular in Iran and has local cultural significance, hence the effort expended. Carps presumably includes the common carp (*Cyprinus carpio*) and other major carps (*Hypophthalmichthys* spp., *Ctenopharyngodon*) farmed in numerous localities as is *Oncorhynchus mykiss* (rainbow trout) which probably accounts for most, if not all, of trout above. The salmon is *Salmo caspius* (Caspian trout), difficult to re-establish its Caspian Sea migratory stocks because of habitat changes.

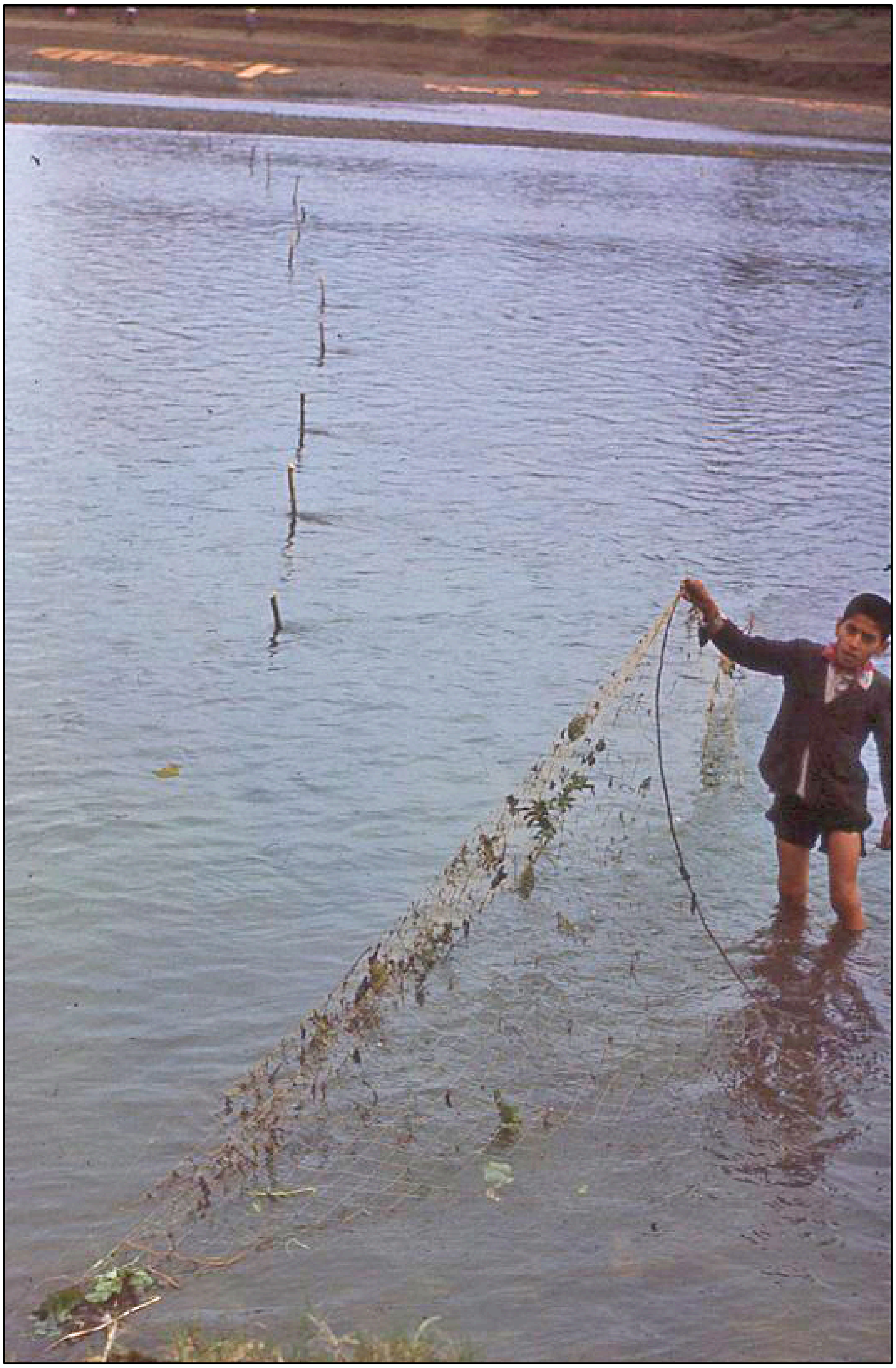
Drought conditions have severely affected fish farming in parts of Iran, e.g., warmwater farming in Golestan and Mazandaran provinces, which lost $6.5 million in 2006 because of low rainfall and the subsequent drought. Output shrank by 5,000 tons in Mazandaran and 1,000 tons in Golestan and projected growth of 15-20% was not attained. This report, from www.agriculturenews.net, downloaded 2 February 2007, noted that Mazandaran alone accounted for 30% of Iran's farm fish production. Gholifar *et al*. (2019) cited levels of warmwater fish farming in Mazandaran (carp fish and caviar) in 2001 and 2011 as 2,766 t and 41,690 t.

Various studies have been carried out on aquaculture facilities or fish farms in Iran, aimed at improving the yield and combating problems. See under the *Cyprinus carpio* account and Coad (2020) for more information on aquaculture in Chinese carps. Some other examples are given below, Ebrahimzadeh Mousavi and Khosravi (2001) found the toxigenic fungi *Aspergillus flavus*, *Alternaria* spp., *Penicillium* spp. and *Fusarium* spp. at a fish farm for common, grass and silver carp in northern Iran. Shahsavani *et al*. (2001) recorded carp pox in common, grass, silver and bighead carp in a fish farm in Mashhad. Rabani and Nourouzi (2002) studied the quality of the water output from the Neka Power Station in the eastern Caspian basin for its possible use in warmwater carp culture, finding it suitable except for dissolved oxygen levels. Yakhchali and Mahmudihesar (2002) surveyed abundance of *Ichthyophthirius multifilis* (a protozoan causing white spot disease) in coldwater fish farms in West Azarbayjan and Seyed Moratzaei *et al*. (2002) studied this parasite's *in vitro* culture. Ebrahimzadeh *et al*. (2003) examined polyculture of female grass carp x male bighead carp with silver, bighead and common carp (final weight gain was not different between hybrids and grass carp, for example). Ghomi Marzdashti and Azari Takami (2004) studied effects of polyculture of silver, common, grass and bighead carp (only bighead showed increased growth, for example). Esteki (2006) determined the best conditions for manuring fish farms. Rahmani and Ehsani (2006) studied ion exchange and air stripping methods for removing ammonium, which could kill fish in culture systems. Safari (2006) sampled bacteria on 51 farms and examined their use in improving chemical conditions. Ghorbani Vaghei and Ahmadi (2007) studied the diversity and abundance of macrozoobenthos at three fish farms for Chinese carps in Gilan. Khaval *et al*. (2010) investigated the use of *Esox lucius* (northern pike) in polyculture carp ponds for removing pests such as frogs, *Hemiculter leucisculus*, *Pseudorasbora parva*, *Carassius auratus* and *Alburnus alburnus* (= *A.*

*hohenackeri*), the weight of *Cyprinus carpio* being 220% higher than a control pond without pike. Fallahi *et al*. (2013) investigated the use of anaerobic fermented cow manure in Chinese carp culture finding survival and yields were higher than in untreated ponds as plankton proliferated and there was also a reduced need for chemical fertilisers. Ghiasi (2014) and Ghiasi *et al*. (2014) also investigated cow manure usage in cyprinoid ponds finding more bacteria compared to a chemically-fertilised pond but no bacteria in fish livers and kidneys, and total hardness, total phosphorus, total dissolved solids and conductivity were higher in the manured pond but biological oxygen demand, dissolved oxygen and transparency were lower. Masrour *et al*. (2013) studied the effectiveness of education on environmental awareness of fish farmers in Gilan Province. Haghparast *et al*. (2014) evaluated the quantitative and qualitative variations of phytoplankton in earthen ponds at Sijaval Cultivation Center, the rearing ponds having an undesirable phytoplankton load. Kamali *et al*. (2014) and Kamali Sanzighi (2015, 2016) studied the diversity, richness, dominance, evenness and frequency of the crustacean zooplankton community in warmwater fish ponds at Gonbad-e Kavus, varying with season and water chemistry. Kamali *et al*. (2014a) also studied the abundance and biodiversity of phytoplankton in relation to physico-chemical factors at Gonbad-e Kavus in an integrated culture of fingerlings and adults. Kamali *et al*. (2014b) carried out a similar study at the same locale on the blue-green algae community, finding water temperature and cultured fishes affected this community. Ahmadi *et al*. (2015) studied physico-chemical characteristics of warmwater fish ponds at Gonad-e Kavus in relation to production. Ahangarzadeh (2015) studied common, grass and silver carp from fish farms in Khuzestan with symptoms of bacterial septicaemia, finding *Aeromonas hydrophila* and related species were responsible. Arab and Rajabi Islami (2016) analysed social and educational incentives motivating students in aquaculture. Samadi and Allahyari (2016) gave data on information seeking behaviour of carp farmers in Rasht Township, Gilan. Rezaeitabar *et al*. (2017) assessed water quality as suitable for Rasht fish ponds. There are other similar studies across Iran on pond aquaculture in general and this is a selection.

Parasites of fishes are common in aquaculture and wild-caught fishes; the species are detailed in each of the **Species Accounts**. *Clostridium botulinum* is present in coastal areas of northern Iran and is a potential food hazard if preservation is inadequate. Contamination rate was 10% in *Sander lucioperca* (pike-perch) and 6.66% in *Salmo trutta* (= *S. caspius* (Caspian trout) if native) (Tavakoli and Razavilar, 2003a, 2003b; Tavakoli and Tabatabei, 2005), 2.2% of smoked carp, 1.1% of fresh carp, 1.1% of smoked kutum and 1.1% of osetr caviar (R. S. E. Khandaghi in 5th International Symposium on Sturgeon, Iranian Fisheries Research Organization, 9-13 May 2005, Ramsar).

Shariati and Nikfetrat (2005) surveyed the attitudes of fishermen to stock enhancement and conservation efforts in Gilan Province and found a significant positive attitude. Overfishing and illegal fishing were commonly cited as major problems. Aghilinejhad *et al*. (2017) studied illegal fishing in the southwestern Caspian Sea, finding poachers' study level, income and job satisfaction were significant factors along with no licence, less value for the protection of aquatic animals and use of non-standard nets in deeper water. Emami and Hosseini (2004) also assessed the participation of fishery cooperatives from Sari in preserving fish resources. Hassani (2021) showed that the Iranian criminal justice system has clear capabilities for proper criminal management of the destruction of fish habitats in Guilan Province.



Gilan, illegal fishing net on the Shalman River, 18 January 1968, Neil B. Armantrout.

Marketing fish in Iran was discussed at www.shilat.com (downloaded 28 February 2007) and in Salehi (2006) including such items as product quality, availability, variety, safety, price control, shelf-life, size control, consumption behaviour, prices, among others. Adeli and Shaabanpour (2007) looked at consumption of aquatic products in Tehran in 2001 and 2005. Per capita consumption rose from 2.8 to 3.46 kg, 16.6% of people preferred more packaged food, and farmed aquatics were consumed more than other products, live *Oncorhynchus mykiss* (rainbow trout) being preferred the most. Salehi and Mokhtari (2008) investigated attitudes in fish consumption among Iranian nutrition experts. The experts listed various factors such as fish market expansion, advertisements and promotions, health factors, and quality and trust in the seller as having effects on the increase of fish consumption in Iran. Adeli *et al*. (2010a) found households in Tehran bought farmed fish 11 times per year, with trout having the highest demand, and reviewed factors preferred by consumers such as live fish and price decrease in competition with wild fish. Adeli *et al*. (2010b) found quality, taste, smell and protein content were the most important purchasing factors in Tehran. Adeli *et al*. (2011) found fish consumption per capita in Tehran was 13.3 kg in 2008, with 6.4 k from farmed fishes, 5.8 kg from wild fishes and 1.1 kg from canned fishes. Protein preferences were poultry, mutton, beef, trout, wild fishes and Chinese carps. Adeli (2014a) investigated situational factors affecting fish purchase and consumption in Tehran such as hygiene, smell, crowding, ventilation, presentation, curiosity, cleanliness and the sellers' appearance. Amirnejad and Heidari Kamalabadi (2015) studied the factors affecting fish consumption by households in Sari on the Caspian littoral and found region of residence, fish health awareness, assessment of poultry and fish meat benefits, the normative pressure of consumption and meal-planning criteria had the biggest impacts. Dadgar *et al*. (2015) measured per capita fish consumption in cities in Markazi Province finding an average of 5.81 kg/yr, with 6.7 kg/yr in urban areas and 4.62 kg/yr in rural areas. Various factors were barriers to consumption and developmental strategies were advanced. Hosseini *et al*. (2016) found price and smell were the main barriers to fish consumption in Sari and income, family size and occupation were significantly correlated with fish consumption. Nutritional value was the most important motivation of consumers. Hosseini and Adeli (2017) found fish consumers in Sari looked for quality, freshness, store hygiene, properties and nutritional value, trust in the seller, price, species taste, availability, size of fish and consumption convenience. A majority of consumers (93.6%) favoured fresh fish over packed (non-canned) fish. Hosseini *et al*. (2016) also examined fish purchases in Sari and found two-thirds of households bought fish less than once a month and only 4.1% on a weekly basis. Marine fish were preferred over farmed fish and coldwater fish over warmwater fish. Fresh, live and canned fish were preferred over frozen, smoked and salted fish. Shokoohi *et al*. (2017) surveyed seasonal integration of the price in wild and farmed fish markets in Fars over five years. Ziaee *et al*. (2017) investigated factors affecting fresh fish consumption in Iran, finding age, education, gender of household head, income, family size, living area, distance to the sea, and price of poultry and meat had a positive impact on consumption while price of fish had a negative impact (not unexpectedly). Adeli and Mirbagheri (2018) estimated the awareness of fisheries students to the benefits of fish consumption and revealed the need for more serious training and more attention to the benefits and nutritional value of fish in their curriculum, so that they could be better promoters of fish consumption among people and their families. Saravani and Keykhah (2018) investigated fluctuation and instability in prices of native and farmed fish from northern Iran including for such native cyprinoids as *Abramis brama*, *Cyprinus carpio* and *Rutilus kutum* and for exotic and farmed *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *H. nobilis*.Adeli *et*

*al*. (2019) studied factors affecting purchase and sale trends in the Gilan ports of Astara, Bandar Anzali and Kiashahr. The unpleasant smell, tiny bones and difficulty of cleaning were factors for consumers from the supplier's perspective while healthiness and freshness were factors from the consumers' viewpoint. Various constraints on and backgrounds of the sellers were tabulated. Moslemi *et al*. (2019) studied factors affecting consumer's behavior in Babolsar, Mazandaran. Most respondents consumed between 10 and 20 kg of fish per year, factors affecting marketing of fish were effective, and fish freshness was the most important factor to consumers. The difficulty of preparing fresh fish compared to packaged fillets was considered to be the least important factor affecting the behavior of consumers. Rahnama and Somogyi (2020) found in face-to-face surveys of Caspian Sea consumers of sea food that safety, nutrition, convenience, weight control, social comparison, ethnocentrism and emotions had positive impact on choice while sensory appeal had no positive impact. Results also revealed that on average social comparison, ethnocentrism and safety were among the most effective factors on choice behavior, whereas convenience, weight control, nutrition, and emotions were among the least effective factors.

Quliyev (2006) detailed fish farming in the neighbouring country of Azerbaijan with relevance to Iranian Caspian Sea basin species.

# Carps
# (Family Cyprinidae)

This introductory section covers aspects of the classification, relationships, morphology and biology of the cyprinoid fishes including the Carps (Cyprinidae), Minnows (Leuciscidae - see Volume II) and related families found in Iran.

The suborder Cyprinoidei contains by far the most species in Iranian fresh waters and is one of the most widespread and speciose in the world, certainly the most speciose in fresh waters. Fossils suggest an origin in East and Southeast Asia where the greatest diversity in genera and species is found today. Colonisation westwards took place in the Oligocene. Middle Eastern cyprinoids came from Asia and more recently from Euro-mediterranean ancestors (Perea *et al*., 2010).

The relationships of cyprinoid families to other families within the Cypriniformes were given in Hensel (1970), Mayden *et al*. (2009), Chen *et al*. (2013), Nelson *et al*. (2016), Stout *et al*. (2016) and Tan and Armbruster (2018). The cyprinoid suborder is found in North America, Eurasia and Africa. Common names in English for species include barbels, barbs, bitterlings, bleaks, breams, carps, chubs, daces, goldfishes, gudgeons, labeos, large barbs, loaches, mountain barbels, riffle minnows, roaches, rudds, shiners, “sharks”, snow “trouts” or snow barbels, tenches, true carps, true minnows, troutbarbs, among many others. There are about 367 genera and over 3,006 species (Nelson *et al*. 2016), about 8.9% of the world’s fishes. In Iran, the suborder is represented by seven families, about 36 native genera (and 6 exotic genera; interpretations of genera are open to change by authors) and about 118 native species (with probably more to be described) found in all the major drainage basins.

Recent studies have recommended elevation of subfamilies within the former family Cyprinidae to the family level (see as examples, for details, conflicting views and further literature:- Saitoh *et al*. (2006), Chen *et al*. (2008), Li *et al*. (2008), Chen and Mayden (2009), Mayden *et al*. (2009), Conway *et al*. (2010), Mayden and Chen (2010), Yang *et al*. (2010, 2012), Yang and Mayden (2010), Tang *et al*. (2010, 2011), Tao *et al*. (2013), van der Laan *et al*. (2014), Stout *et al*. (2016), Betancur-C *et al*. (2017), Huang *et al*. (2017), Schönhuth *et al*. (2018), Tan and Armbruster (2018), www.cypriniformes.org with Nelson *et al*. (2016), and other works listed below, while noting that not all families are recognised by all workers and assignment of some genera varies).

The classification in the *Catalog of Fishes* (downloaded 11 October 2018) is as follows and this source should be checked for updates for these Iranian members:-

Family **Cyprinidae** Rafinesque, 1815 (carps)
Subfamily **Labeoninae** Bleeker, 1859 (labeonines)
*Bangana*, *Garra*, *Tariqilabeo*
Subfamily **Torinae** Karaman, 1971 (large barbs)
*Arabibarbus, Carasobarbus*, *Mesopotamichthys*
Subfamily **Cyprininae** Rafinesque, 1815 (carps)
*Carassius*, *Cyprinus*
Subfamily **Barbinae** Bleeker, 1859 (barbels)
*Barbus, Capoeta*, *Cyprinion*, *Luciobarbus, Schizocypris*
Subfamily **Schizothoracinae** McClelland, 1842 (snow barbels)
*Schizothorax*

Subfamily **Schizopygopsinae** Mirza, 1991 (mountain barbels)
*Schizopygopsis*
Family **Danionidae** Bleeker, 1863 (danionids)
Subfamily **Chedrinae** Bleeker, 1863 (troutbarbs)
*Barilius*, *Cabdio*
Family **Xenocyprididae** Günther, 1868 (East Asian minnows)
*Ctenopharyngodon*, *Hemiculter*, *Hypophthalmichthys*, *Mylopharyngodon*
Family **Tincidae** Jordan, 1878 (tenches)
*Tinca*
Family **Acheilognathidae** Bleeker, 1863 (bitterlings)
*Rhodeus*
Family **Gobionidae** Bleeker, 1863 (gobionids)
*Gobio*, *Pseudorasbora*, *Romanogobio*
Family **Leuciscidae** Bonaparte, 1835 (minnows)
Subfamily **Leuciscinae** Bonaparte, 1835 (leuciscines)
*Abramis*, *Acanthobrama*, *Alburnoides*, *Alburnus*, *Ballerus*, *Blicca*, *Chondrostoma*, *Leucaspius*, *Leuciscus*, *Pelecus*, *Rutilus*, *Scardinius*, *Squalius*, *Vimba*

The families are defined mostly by molecular and osteological characters that do not lend themselves to field and key identifications.

The suborder Cyprinoidei (Carps, Minnows and relatives) is comprised of small to very large fishes (1.0 cm and up to 3.0 m, with some of the largest members in Iran) characterised by throat or pharyngeal teeth in 1-3 rows with a maximum of 8 teeth in a row, tooth counts and form are often characteristic of the genus or species, no jaw teeth, body form various from fusiform to compressed, lips are usually thin and not sucker-like (but can show hypertrophy), the upper jaw is bordered by the premaxillae bones and usually protrusible, barbels are absent or present in 1-3 pairs (not more than two pairs in Iranian species), body covered in cycloid scales, in some species easily lost, while the head is scaleless, no adipose fin, absence of an uncinate process on epibranchials one and two, absence of pharyngobranchial one, pharyngobranchial two overlapping with pharyngobranchial three, the anterior four vertebrae are modified for conduction of sound from the air bladder to the ear and are known as the Weberian apparatus, pelvic fins are abdominal in position, no pyloric caeca, air bladder usually present and well-developed, connected to the gut by a duct, and not enclosed in a bony capsule, no true stomach, branchiostegal rays always 3 in number, no true spines in the fins although in some the last dorsal fin **un**branched ray (at the front of the fin) may be thickened and spine-like and, in *Cyprinus* and *Carassius*, the last anal fin unbranched ray is also thickened. The primitive chromosome number is 2n = 50 but polyploidy is common and seen in *Cyprinus*, *Carassius* and in the schizothoracines. Collares-Pereira (1994) argues that the polyploid condition (e.g., 2n = 100) is primitive or plesiomorphic. Li and Guo (2020) discussed the adaptive and evolutionary significance of polyploidy in Cyprinidae.

There are 2-4 unbranched rays (including rudimentary ones) in the dorsal and anal fins followed by the more numerous branched rays (the last two branched rays are counted as one in this work). The first pectoral and the first pelvic fin ray are unbranched and not included in counts. Pharyngeal teeth lie on a modified, fifth gill arch which can be seen or probed behind the shoulder girdle, just inside the gill opening. The arch has to be removed with dissecting equipment to count the teeth. Tooth counts are presented as a formula such as 2,5-4,1 which

indicates 2 teeth in the outer left row and 4 on the inner right row. Teeth may be lost from major or minor rows so variant formulae are given after the principal one. A horny pad on the underside of the basioccipital bone of the skull is used to masticate the food against. Tooth form varies with the food - molar-shaped teeth are used to crush molluscs, flat but grooved surfaces for grinding plant food, and sharp edged teeth for slicing various invertebrate foods.

Two subfamilies as recognised formerly, the Alburninae and Leuciscinae, are paraphyletic but together seem to form a monophyletic group with a radiation about 20 million years ago, based on allozyme, cytochrome *b*, 16S rDNA and mitochondrial control region data from European cyprinoids (Hänfling and Brandl, 2000; Gilles *et al*., 2001). These two subfamilies contain many Iranian genera (see below under Leuciscinae). Zardoya and Doadrio (1999) analysed the cytochrome *b* nucleotide sequence of a variety of cyprinoids, mostly European, and found support for two subfamilies Cyprininae (including barbins) and Leuciscinae (including cultrins, tincins, gobionins, phoxinins and alburnins + leuciscins). The origin of cyprinoids was estimated at 38.9 MYA and the separation of Cyprininae and Leuciscinae at 27.7 MYA. They also found the phylogenetic utility of barbel possession to be limited as it was acquired independently in the two subfamilies. The number of rows of pharyngeal teeth was a more reliable phylogenetic marker, at least at the generic level.

Perea *et al*. (2010) using mitochondrial and nuclear DNA gave details of major cladogenetic events in the leuciscin lineages in the circum-Mediterranean, involving genera and species found in Iran.

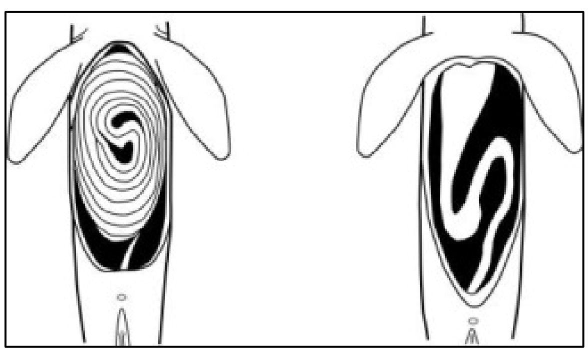
Yang *et al*. (2010, 2012, 2015) and Yang and Mayden (2010) studied the molecular phylogeny of the subfamily Cyprininae and these works should be consulted for further details of tribal relationships and anatomy. Cyprininae are represented in Iran by the genera *Bangana*, *Garra* (and *Tariqilabeo*) (tribe Labeonini), *Arabibarbus*, *Carasobarbus* and *Mesopotamichthys* (tribe Torini), *Carassius* (introduced) and *Cyprinus* (tribe Cyprinini), *Schizothorax* (tribe Schizothoracini), *Schizopygopsis* (tribe Schizopygopsini), *Barbus*, *Capoeta*, *Cyprinion* and *Luciobarbus* (tribe Barbini) and *Schizocypris* (*incertae sedis*).

Durand *et al*. (2002a, 2002b) using cytochrome *b* DNA of Cyprinoidei concluded that the Middle East is an important interchange area for this freshwater ichthyofauna rather than a centre of speciation. The Middle East leuciscine cyprinoids have Europe as an important Palearctic influence consistent with the Lago Mare dispersion while the cyprinine cyprinoids showed three highly divergent lineages, namely one shared with the Euro-Mediterranean area (*Barbus*/*Luciobarbus*), a relict of the Lago Mare dispersion, one shared with Africa (*Carasobarbus*/*Varicorhinus* subgenus) and one with Asia (*Garra*). The Lago Mare dispersion occurred during a salinity crisis in the Mediterranean Sea 5.5 MY ago in the Late Miocene when freshwater fish were able to disperse through oligohaline or fresh water in the Paratethys Sea to reach the Middle East (Bianco, 1990). Some data of Durand *et al*. (2002a, 2002b) conflicted with this scenario - the *Carasobarbus* clade that includes *Barbus* (= *Arabibarbus*) *grypus* showed a separation divergence later than the salinity crisis in the Pliocene when no migration route was available. Note that some authors placed *grypus* in the Indian genus *Tor* and that it is now recognised as a member of the Middle Eastern genus *Arabibarbus*.

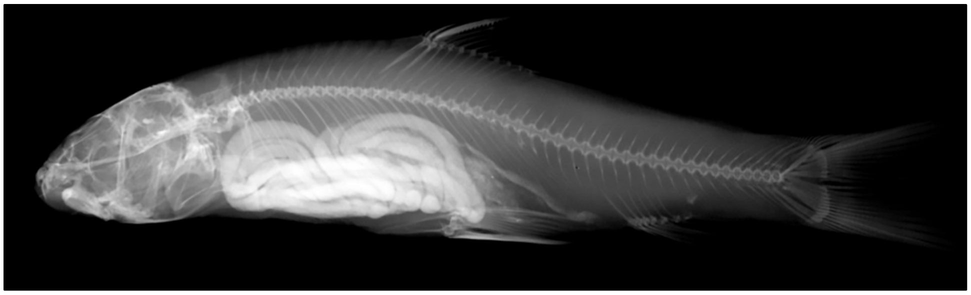
Other Middle Eastern cyprinoid genera were regarded by Durand *et al*. (2002a, 2002b) as relicts of older colonisation waves and showed an eastern influence consistent with an Asian origin of the Cyprinoidei. *Cyprinion* has no sister species in the Euro-Mediterranean area and has been isolated in the Middle East since before the salinity crisis, 7.8-8.8 MY ago. *Cyprinion* may have entered the Middle East during the colonisation event that isolated the genera *Barbus sensu*

*lato* and *Schizothorax* in the European and Asian basins respectively. The divergence of these species is similar in time to the radiation of the Leuciscinae (now Leuciscidae) supposedly centred in Siberia based on fossil records. Siberia was probably an important dispersion centre for both Leuciscinae and Cyprininae at that time. Otero (2001) described as questionably a *Barbus* sp. from the Lower Miocene of Saudi Arabia showing an early date for the entry of cyprinoids to the Afro-Arabian Plate.

Some species may enter brackish water but the family is primarily a freshwater one. Cyprinoids have extremely sensitive hearing via the Weberian apparatus and this is thought to account for their success. They produce an alarm substance when injured. This chemical stimulates related species to flee and to hide, another useful adaptation. Cyprinoids are remarkable for changes they undergo during the spawning season. Some fish, which are usually silvery, develop bright reds and yellows. Nuptial, pearl or breeding tubercles develop on the head, scales and fin rays often in distinct patterns, and there are swellings of the head or fin rays in some species. These changes are most apparent in males. Tubercles and swollen rays are used to clasp females during the spawning act. Generally, males have longer pectoral fins than females. Tubercles are used also to fight other males and defend and clean nests. Colour attracts females for mating. Nest building males are larger than females, the reverse of the situation in most fishes where egg-bearing females are the largest. Not all species build nests and some simply broadcast eggs over weeds, gravel or sand. Fractional spawning is common in these species. This is a prolonged spawning season which ensures no single batch of eggs is lost to unfavourable, temporary environmental changes such as floods. Cyprinoids are mostly omnivores, feeding on small crustaceans, insects and some minute plants but some specialise in eating large plants, or other fishes. Diet is reflected in pharyngeal tooth shape as mentioned above. Gut length is important too. A long, coiled intestine indicates a reliance on plant material that takes longer to digest. A simple, s-shaped gut is found in insectivorous fish. A black peritoneum is thought to protect gut bacteria from damaging light. The bacteria aid in breaking down the strong cell walls of plants. Size and shape of the mouth are also indicative of diet. These fishes are found in many diverse habitats from swift, cold streams to warm bogs. They are schooling fishes, especially when young.



Coiled and s-shaped intestines, ventral views,
@ Canadian Museum of Nature.



*Capoeta umbla*, 96.4 mm standard length, CMNFI 2007-0109 to show coiled gut, Noel Alfonso @ Canadian Museum of Nature.

Cyprinoids play an important role in fresh waters as food for other fishes and some species are commercially important as bait fish, as sport fish or as food in Asian countries. Raising "minnows" as bait and as forage fish for sport fish is a big business in the U.S.A. They are an important element in the commercial aquarium trade and certain species are used in experimental studies by scientists. Cyprinoids were also important in the past, sacred fish ponds being reported from Mesopotamia in 3,000 B.C., and in Iran today cyprinoids associated with mosques and shrines are "sacred". A general review of Eurasian cyprinoids was given by Bănărescu and Coad (1991).

Cyprinoid family members are particularly important in Iran in aquaculture, reviewed above under **Fisheries**. The Chinese carps (*Cyprinus carpio* or common carp, also native to Iran, *Ctenopharyngodon idella* or grass carp, *Hypophthalmichthys molitrix* or silver carp, and to a lesser extent *Hypophthalmichthys nobilis* or bighead carp) are the main species used in warmwater culture in almost all the provinces of Iran (see Coad (2020)). Experiments in the Caspian region for artificial propagation of native *Aspius* (= *Leuciscus*) *aspius* and *Barbus brachycephalus* (= *Luciobarbus caspius*) to enhance stocks, and for farming *Rutilus frisii* (= *R. kutum*) and *Abramis brama* using mono- and polyculture along with Chinese carps have been carried out (*Iranian Fisheries Research and Training Organization Annual Report*, 1992-93; *Annual Bulletin* 1993-94, *Iranian Fisheries Research and Training Organization, Tehran*, pp. 77-78, 1995).

Extensive studies have been carried out on the parasitology of these fishes in Iran and these are briefly described under the particular species descriptions. Ebrahimi *et al*. (2018) examined cyprinoids from West Azarbayjan Province without specifying the fish species and found the ectoparasites *Ichthyophthirius multifilis, Argulus* sp., *Dactylogyrus* spp. and *Gyrodactylus* sp. at a prevalence of 60.7%.

Many cyprinoid species can be caught on hook and line by various angling techniques but outside the larger rivers of Khuzestan and the Caspian shore, this hobby was not much pursued prior to the 1980s. Even small species and specimens can give some sport on light tackle such as worm-baited hooks. Species caught include *Arabibarbus grypus*, *Capoeta trutta*, *Carasobarbus luteus*, *Cyprinion macrostomus*, *Cyprinus carpio*, *Garra rufa*, *Luciobarbus barbulus, Luciobarbus esocinus* and *Squalius* spp. among others. Increasingly, sport fishing for a variety of carps and minnows is found in Iran, with competitions, websites, Facebook pages, YouTube, Pinterest and other social media entries, e.g., see Iran Fish Species in https://themissionflymag.com/ (downloaded 2 March 2019).

Fingerlings of *Labeo rohita*, an Indian carp, were imported to Gilan in Iran in 2004 to enrich the diversity of cultured fish and increase protein production. There is always the potential for escapes and establishment of this exotic. Additionally, Hoseinzadeh Sahafi (2012), Mortezavi

Zadeh *et al*. (2012) and Mortezavizadeh (2013) reported on pond-cultured *Catla catla*, *Labeo rohita* and *Cirrhinus reba* (Indian carps) in Khuzestan where the climate may well favour any escapees - the fish survived a January-September temperature regime of 7-34°C (*Labeo rohita* is now found in the Karun River, Khuzestan - see **Checklists**). Three Indian carps (*Cirrhinus mrigala*, *Catla catla*, *Labeo rohita*) have also been cultured in Sistan (Rezvani Gilkolaei *et al*., 2012). Kianersi (2017) analysed the environmental effects of Indian carps (including also *Cirrhinus molitorella*, *C. mrigala* and *Labeo calbasu* in addition to the three species initially listed above) introduced to the Azadegan Warmwater Fish Culture Centre in Khuzestan and found negative effects due to sewage production and on water resources but positive effects on the economic and social environment.

Hajimirrahimi and Dadgar (2016) reviewed the development of ornamental fish farming in Markazi, a leading province in this industry, which might become a source of exotic cyprinoids. Saeedi *et al*. (2015) recorded fungal infections on aquarium fish in breeding centres in Golestan Province, a potential source for infection of native species. Barghi Lashkari *et al*. (2017) reported on effective factors in production and marketing of ornamental fish based on 40 members of the ornamental fish production cooperation in Alborz Province, also indicating the extensive development of this industry. Gharavi *et al*. (2018) commented on the threat from parasites brought in on imported aquarium fishes. There is also an extensive aquarium fish-culture industry in southern Iraq, an additional source of exotic cyprinoids that could reach adjacent Iranian waters (Coad, 2010). Deliberate and accidental releases of aquarium fishes in native waters is likely to be an ongoing problem as many waters are warm enough to sustain these exotics. Even winterkill of some species would not prevent exotic parasites and diseases becoming established in the native fauna.

A general review of Iranian cyprinid fishes (i.e., cyprinoids) is given in Farsi by Ramin (2017).

The layout of the species accounts, with details and explanations of content, is given in the **Purpose of the Work** section above.

# Identification Keys

The cyprinids of Iran can be identified using the following keys, the first to genera and the subsequent ones to species within genera having more than one species. Most genera, with a little experience, are recognisable without a key by a combination of general features.

Note that key characters, e.g., fin ray counts, presence/absence of barbels, etc., are restricted to Iranian species; species from elsewhere may not key out here.

Ideally, each couplet has a series of characters that reinforce each other and allow for any loss or damage to characters. Additionally, some characters are key but difficult to interpret without experience, or are internal and require dissection that is not always possible. In some cases, only one character is available since it must encompass all included species below that point in the key. Since some species are relatively difficult to identify on external morphology, additional characters may be given in brackets [....]. These additional characters are not unique to the species but, in combination, help to identify the species.

General body form is often quite similar within a genus with details of the mouth, counts of meristic characters, internal characters and distribution being important. Some species are, as yet, poorly defined on external anatomy which may be due to a lack of knowledge or their great similarity to related species, their distinction being founded on molecular evidence.

If used properly, a key is more accurate and less time consuming than flicking through pages of text. The disadvantage of keys is that the alternative state in each couplet is not at hand if you only have one fish to examine, and a simple error can lead you widely astray. Some recognised species have overlapping counts for obvious meristic characters, although means and modes are significantly different, and differ in other, subtler ways not readily summarised in a key. Ideally, a student of fishes should collect a series of individuals of different sizes and sexes from each locality, wherever conservation demands and practicality permits. A series of about 30-40 specimens allows for character variations dependent on sex and size, and on abnormalities, and also allows for comparative measurements and counts to be made. In addition, a more careful examination may reveal more than one species in the sample.

The most important characters for identification are the general body shape, the presence and number of barbels, the position, shape and size of the mouth, the number of scales along the flank, the number of rays in various fins, and the number of gill rakers, among others. Although colour is often a useful guide, it can also be misleading. Fish vary their colour to match their background or for spawning rituals. In general, it is best to use several characters to identify a fish rather than relying on a single one which can easily be misleading.

Large fishes can be examined for these characters using the naked eye, but various pieces of equipment are necessary for identification of smaller species or juveniles. Hand lenses are of some use in magnifying small characters but by far the best instrument is a binocular microscope that can magnify up to 50 times. Pharyngeal teeth, fin rays and scales can be counted with ease using a microscope. Attachments can be used to take photographs or project images of structures for drawing. Measurements can be taken under a microscope on small specimens to ensure accuracy, and a microscope leaves both hands free to handle the specimen and dissecting tools or calipers. Ichthyologists develop their own techniques for manipulating light sources and specimens for making structures readily visible. Two light sources are useful. One of these illuminates the surface of the fish for scale counts and observation of structures. The other one bounces light off a white enamel tray into the microscope and is particularly useful for counting fin rays as the light travels through the fin enabling clear distinction of rays.

Two types of forceps are very useful. A large pair (25-35 cm long) enables specimens to be taken out of a jar and sorted without immersing one's fingers. Preservative solutions will irritate the skin and contact should be minimised; some ichthyologists wash the specimen in water before handling, but this may compromise subsequent effectiveness of preservatives. Fine plastic gloves can be worn, but some people develop allergies to latex. A very fine pair of forceps with needle-like points is used to spread folded fins to see the rays and to probe and examine other structures.

Scissors are necessary for slitting the belly and these will vary in size depending on the size of the fish. Fine scissors can be useful in dissection. Very large fish may require a sharp knife or scalpel for dissection or slitting the abdomen. The slit is usually made on the right side of the fish as the left side (head to left) is used for drawings and photographs.

A needle mounted on a wooden or metal handle can be used for cleaning gill arches of debris, clearing flesh from pharyngeal arches or lifting the edges of scales to help in counting them. Most commercial dissecting needles are too blunt and a fine needle can be taped on the end.

Measurements are best made with calipers for accuracy. Dial or electronic calipers are available which measure to an accuracy of 0.1 mm, and are available in several lengths. Very large calipers are usually vernier calipers, but an accuracy of 0.1 mm for large specimens is not required, or even attainable.

Examination of minute scales, debris encrusted gill arches or the lateral and cephalic line canals is facilitated by using compressed air delivered through a glass tube of 1 mm diameter. The air can come from a compressor or aquarium air pump, or even from a hand-squeezed bulb.

Distribution is often an important aid in assigning samples to a species. The distributions given here are necessarily based on current data and refer to Iran only as noted above; further field work may well expand species ranges to other basins in that country and from other countries to Iran. Distributions in the keys are by 19 drainage basins (see **Biodiversity**), except for exotic species that may occur widely as farmed fish or as accidental and deliberate releases that have not always been well documented. Native fishes that were translocated are mentioned. The fauna differs between drainage basins, e.g., *Cyprinion* species are only found in the west and south.

Thickened fin rays are referred to as spines for convenience in this key, although they are not true spines.

Characters in brackets [….] may not apply to all genera or species below them in the key but are additional characters that aid identification for that particular genus or species.

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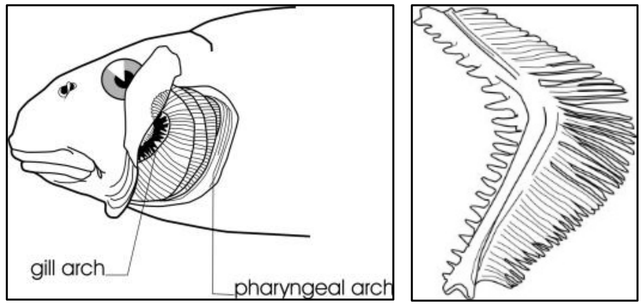
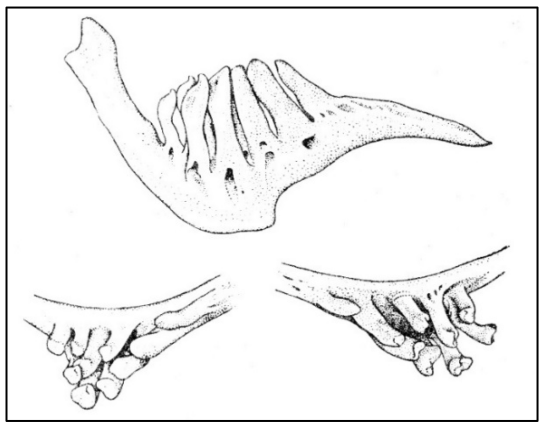
## Key to Genera of Cyprinidae

Species that are the only one in the genus will key out here and are illustrated. Illustrations are taken from the **Species Accounts** where the source is acknowledged. A few general illustrations follow to show characters that appear repeatedly in the keys to both Carps and Minnows.




Position of gill and pharyngeal arches (left), gill arch to show gill rakers at left and gill filaments at right (right) @ Canadian Museum of Nature.



Pharyngeal teeth in three rows from several angles in *Schizothorax zarudnyi*, after Annandale and Hora (1920).

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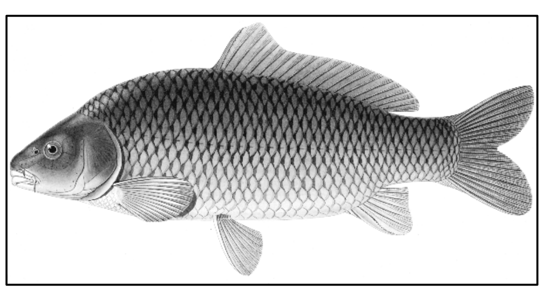
1a. Serrated stiffened ray (spine) in the dorsal **and** anal fins near the origin; dorsal fin elongate (12-23 branched rays); anal fin origin below dorsal fin ---> **2**
1b. No serrated stiffened ray (spine) in the anal fin; dorsal fin short to moderately elongate (6-17, most species 10 or less, branched rays); anal fin origin usually behind dorsal fin base end ---> **3**

2a. Barbels absent; pharyngeal teeth in one row; exotic = *Carassius*
2b. Barbels present (two pairs); pharyngeal teeth in three rows; native in Caspian Sea and Hari River basins, and introduced widely = *Cyprinus carpio*

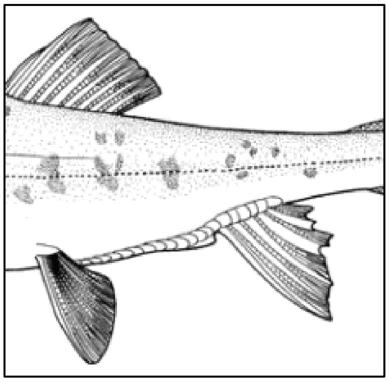


*Cyprinus carpio*

3a. Eyes absent; body pink through lack of pigment (white in preservative); usually no scales or very few; Loven and Tashan caves, Tuveh Spring = *Garra* (in part)
3b. Eyes present; body pigmented; scales present (rarely restricted to anal area where enlarged) ---> **4**

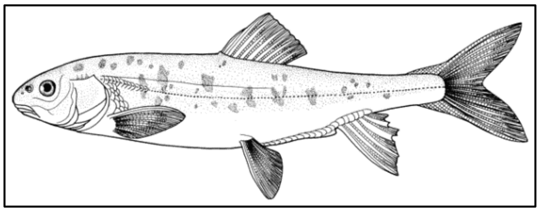
A cave fish, *Garra tashanensis*

4a. Anus and anal fin base sheathed by markedly enlarged scales ---> **5**
4b. Anus and anal fin base not sheathed by markedly enlarged scales ---> **7**



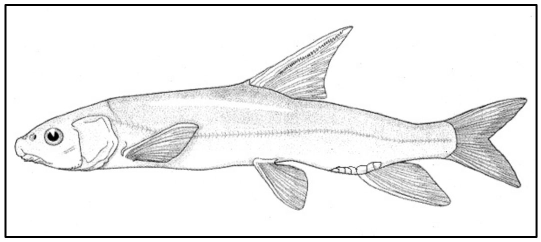
Enlarged scales at anus and anal fin base in *Schizopygopsis stolickai*

5a. Scales mostly absent; pharyngeal teeth in two rows; [no barbels]; Sistan basin = *Schizopygopsis stolickai*
5b. Scales present; pharyngeal teeth in three rows = **6**



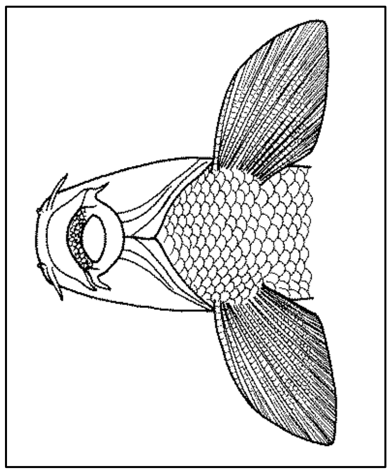
*Schizopygopsis stolickai*

6a. Barbels absent or vestigial; pharyngeal tooth formula 2,3,4-4,3,2; anal fin branched rays 6; Sistan basin = *Schizocypris altidorsalis*
6b. Barbels present and well-developed; pharyngeal tooth formula 2,3,5-5,3,2; anal fin branched rays 5; Dasht-e Kavir, Hari River and Sistan basins = *Schizothorax*



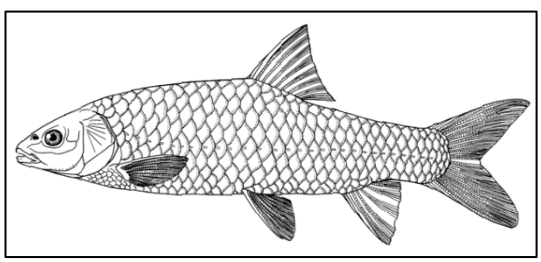
*Schizocypris altidorsalis*

7a. Adhesive disc prominent on the ventral head; eastern, southern and western Iran = *Garra* (in part)
7b. No adhesive disc ---> **8**

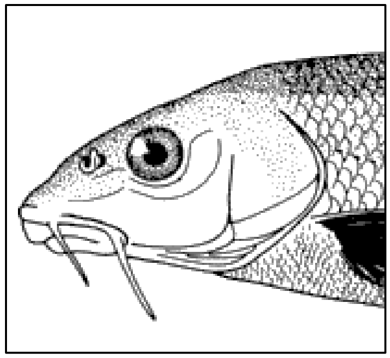


Ventral head with adhesive disc
in *Garra persica*

8a. Barbels absent; Persis and Tigris River basins, introduced to Kor River basin = *Mesopotamichthys sharpeyi*
8b. Barbels present ---> **9**

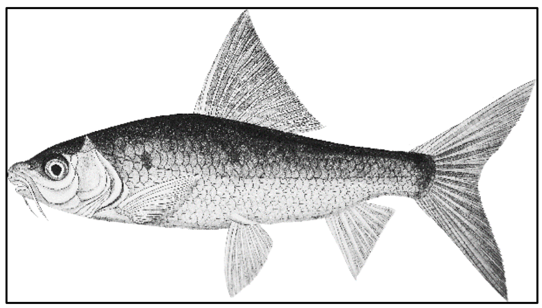


*Mesopotamichthys sharpeyi*



Head of *Luciobarbus barbulus*
to show barbels

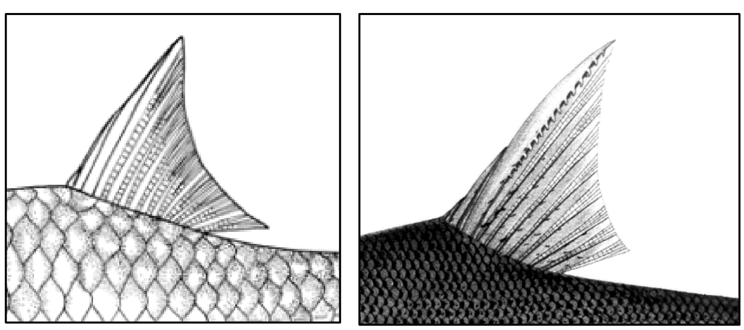
9a. Total gill rakers more than 33; Hamun-e Mashkid basin = *Bangana dero*
9b. Total gill rakers 33 or less, usually less than 30 ---> **10**



*Bangana dero*

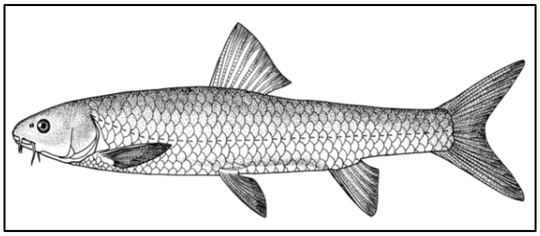
10a**.** Lobate papillae behind lower lip; upper jaw fully enclosed by the lip and the median part of the upper lip covered by the rostrum; Hamun-e Mashkid, Makran and Sistan basins = *Tariqilabeo*
10b. Not as above ---> **11**

11a. Last dorsal fin *unbranched* ray thickened as a smooth spine ---> **12**
11b. Last dorsal fin *unbranched* ray thickened as a spine with posterior denticulations or teeth ---> **13**



Smooth and denticulated spines in dorsal fins of
*Carasobarbus sublimus* and *Capoeta trutta*

12a. Anal fin branched rays modally 5; dorsal fin branched rays modally 8; Hormuz, Persis and Tigris River basins ---> *Arabibarbus grypus*
12b. Anal fin branched rays modally 6; dorsal fin branched rays modally 9-10; [median lower lip lobe in two of three species]; Hormuz, Persis and Tigris River basins = *Carasobarbus*



*Arabibarbus grypus*

13a. Dorsal fin branched rays 9-17, usually 10 or more; anal fin branched rays modally 7; southern and western Iran = *Cyprinion*
13b. Dorsal fin branched rays modally 7, 8 or 9; anal fin branched rays modally 5 ---> **14**

14a. Mouth a shallow arch (sector-shaped) with ventral cutting edge (u-shaped in young); one pair of barbels (very rarely two pair, commonly two pair in *C. heratensis* in the Hari River basin); widely distributed = *Capoeta*
14b. Not as above ---> **15**

Sector mouth in *Capoeta* spp.

15a. Papillose lower lip separated from the chin by a groove; nuptial tubercles small and numerous on head and anterior body; Caspian Sea, Dasht-e Kavir, Esfahan, Hormuz, Lake Maharlu, Lake Urmia, Namak Lake, Persis and Tigris River basins = *Barbus*
15b. Lower lip without papillae and continuous with the chin; nuptial tubercles few and large on snout; Caspian Sea, Hormuz, Kor River, Lake Urmia, Persis and Tigris River basins = *Luciobarbus*

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## Verbal Key to Genera of Cyprinidae

The key characters of the genera are summarised below, restricted to Iranian species only. Characters may not be unique to a genus, e.g., anal fin spine in both *Carassius* and

*Cyprinus*, but the combination of characters is unique as one genus has barbels and the other has not in this example.

*Arabibarbus*: dorsal fin spine smooth, barbels, dorsal fin branched rays 8, anal fin branched rays 5, Hormuz, Persis and Tigris River.
*Bangana*: upper jaw fully enclosed by the lip and the median part of the upper lip covered by the rostrum, Hamun-e Mashkid.
*Barbus*: papillose lower lip separated from the chin by a groove, nuptial tubercles small and numerous on head and anterior body, northern and western Iran.
*Capoeta*: sector mouth, anal fin branched rays 5, dorsal fin rays 7-9, throughout Iran.
*Carasobarbus*: dorsal fin spine smooth, barbels, dorsal fin branched rays 9-10, anal fin branched rays 6, western and southern Iran.
*Carassius*: anal fin spine, no barbels, exotic.
*Cyprinion*: sector mouth, anal fin branched rays 7, dorsal fin branched rays 9-17, western and southern Iran.
*Cyprinus*: anal fin spine, barbels, Caspian Sea, Hari River and exotic.
*Garra*: chin sucker present, and/or no eyes or pigment, eastern, southern and western Iran.
*Luciobarbus*: lower lip without papillae and continuous with the chin, nuptial tubercles few and large on snout; northern, western and southern Iran.
*Mesopotamichthys*: dorsal fin spine smooth, no barbels.
*Schizocypris*: anus and anal fin base sheathed by enlarged scales, body scales present, anal fin branched rays 6, Sistan.
*Schizopygopsis*: anus and anal fin base sheathed by enlarged scales, body scales mostly absent, Sistan.
*Schizothorax*: anus and anal fin base sheathed by enlarged scales, body scales present, anal fin branched rays 5. Dasht-e Kavir, Hari River and Sistan.
*Tariqilabeo*: lobate papillae behind lower jaw, Hamun-e Mashkid, Makran and Sistan.

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**Key to Species within Genera of Cyprinidae**

Note that some species have been defined by DNA while morphological differences comprise overlapping characters ("characters in combination, none unique") and so individual specimens may be difficult to identify in the field, the laboratory, or in the literature based on external morphology. Distribution is therefore often important. A single species is shown to represent each genus as body form is generally similar.

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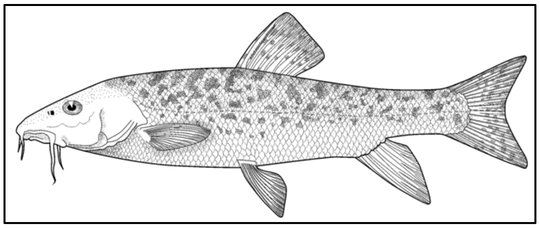
**Key to *Barbus***


*Barbus lacerta*

1a. Median pad of lower lip well-developed = **2**
1b. Median pad of lower lip shallow or small or absent ---> **3**


Well-developed median pad

2a. Lateral line scales 59-70, modes 61 and 64 in different studies; scales around caudal peduncle 26-29; Karun River, Tigris River basin = *Barbus karunensis*
2b. Lateral line scales 64-85, mean 79.6; scales around caudal peduncle 14-23; [lateral line scales means and modes less than 60 in *B. cyri*]; Mahabad River, Lake Urmia basin = *Barbus urmianus*

3a. Lateral line scales 69-90 (modes 77 and 82 in different studies); last unbranched dorsal fin ray denticles covering 80-95% of ray; Dasht-e Kavir and Namak Lake basins = *Barbus miliaris*
3b. Lateral line scales 50-73 (modes 57 and 61); last unbranched dorsal fin ray denticles covering 60-70% of ray ---> **4**

4a. Lateral line scales 50-87 (mode 57); convex anal fin margin; wide upper lip (7-9% head length); rectangular gular region; Caspian Sea and Lake Urmia basins = *Barbus cyri*
4b. Lateral line scales 52-67 (mode 61); straight anal fin margin; narrow upper lip (4-6% head length); triangular gular region; Esfahan, Hormuz, Lake Maharlu, Persis and Tigris River basins = *Barbus lacerta*

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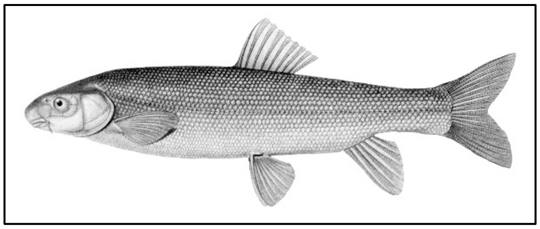
## Key to *Capoeta*



*Capoeta buhsei*

The following key leaves something to be desired. Several species are delimited primarily by DNA and their morphology, as currently understood, overlaps. Distribution is often key. Note that count ranges may overlap somewhat at their extremes (so values in parentheses give a more restricted range, usually encompassing more than 90% of fish), modal values are usually very strong when cited, species are best identified from a broad sample taken from a locality rather than an individual specimen, "usually" indicates that some fish may not possess the character cited but a moderate sample will be indicative, and characters in brackets are not unique to the species or overlap somewhat but work in combination and exclude syntopic species which sometime appear remotely in the key. Note that three species (*C. anamisensis*, *C. capoeta* and *C. mandica*) have lateral line scale counts that broadly overlap the division between the small- and large-scaled groups and so key out in both groups.

1a. Lateral line scales usually 60 or less, scales between dorsal fin and lateral line usually 10 or less, large-scaled group ---> **2**
1b. Lateral line scales usually 61 or more, scales between dorsal fin and lateral line usually 12 or more, small-scaled group ---> **11**

2a. Two pairs of barbels (some have only one pair); [total gill rakers 21-24]; Dasht-e Kavir and Hari River basins = *Capoeta heratensis*
2b. Almost always one pair of barbels (rare individuals with 3 or 4 barbels) ---> **3**

3a. Modally 7 dorsal fin branched rays [lateral line scales 40-62 (46-56); total gill rakers 11-21 (14-17)]; Bejestan, Dasht-e Lut, Dasht-e Kavir, Hari River and Sistan basins = *Capoeta fusca*
3b. Usually 8 or 9 dorsal fin branched rays; total gill rakers 15-32 ---> **4**

4a. Modally 9 dorsal fin branched rays; body colour bluish; [lateral line scales 52-60]; Aras River in Caspian Sea basin = *Capoeta kaput*
4b. Modally 8 dorsal fin branched rays; body not bluish ---> **5**

5a. Body and head with irregular brown to black speckles; [lateral line scales 57-68; scales between dorsal fin and lateral line 12-16]; Hormuz and Persis basins = *Capoeta mandica*
5b. Body without speckles ---> **6**

6a. Caspian Sea (Aras River basin) and Lake Urmia basins; [lateral line scales 46-70; scales between dorsal fin and lateral line 7-11] = *Capoeta capoeta*
6b. Other basins ---> **7**

7a. Hormuz basin; [lateral line scales 56-67; scales between dorsal fin and lateral line 11-13; total gill rakers 21-25; young may be finely spotted on flanks] = *Capoeta anamisensis*
7b. Other basins ---> **8**

8a. Caspian Sea basin (excluding Aras River basin); [lateral line scales 39-59 (49-57)] = *Capoeta razii*
8b. Outside Caspian Sea basin ---> **9**

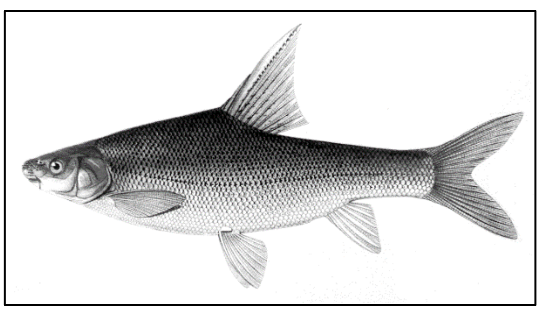
9a. Namak Lake and western Dasht-e Kavir basins; [lateral line scales 36-52; scales between dorsal fin and lateral line 6-10] = C*apoeta aculeata*
9b. Other basins ---> **10**

10a. Esfahan basin; lateral line scales 51-60; scales between dorsal fin and lateral line 9-11 = *Capoeta gracilis* (and note a putative other species in the Esfahan basin with 32-46 lateral line scales which authors have referred to as *C. gracilis*)
10b. Kerman-Na'in, Kor River, Persis and Tigris River basins; lateral line scales 37-51; scales between dorsal fin and lateral line 6-9 = *Capoeta macrolepis*

11a. Scales between dorsal fin and lateral line 18 or more; Tigris River basin = *Capoeta umbla*
11b. Scales between dorsal fin and lateral line 17 or less ---> **12**

12a. Body and head with irregular brown to black speckles ---> **13**
12b. Body and head without irregular brown to black speckles ---> **14**

13a. Dorsal fin spine strongly developed, longer than head; [lateral line scales 61-90, often more than 70; scales between dorsal fin and lateral line 9-14; total gill rakers 20-33]; Persis and Tigris River basins = *Capoeta trutta*
13b. Dorsal fin spine not as strongly developed, moderate; [lateral line scales 57-68; scales between dorsal fin and lateral line 12-16; total gill rakers 21-30]; Hormuz and Persis basins = *Capoeta mandica*




Strong dorsal spine in *Capoeta trutta* left and moderate dorsal spine in *Capoeta mandica* right

14a. Caspian Sea (Aras River basin) and Lake Urmia basins; [lateral line scales 46-70 scales between dorsal fin and lateral line 7-11] = *Capoeta capoeta*
14b. Outside Caspian Sea basin ---> **15**

15a. Total gill rakers 21-25; [lateral line scales 56-67; scales between dorsal fin and lateral line 11-13]; Hormuz basin = *Capoeta anamisensis*
15b. Total gill rakers 21 or less; [lateral line scales usually 67 or more; scales between dorsal fin and lateral line 9-17, mostly 12-17 ---> **16**

16a. Namak Lake and western Dasht-e Kavir basins; [lateral line scales 72-99] = *Capoeta buhsei*
16b. Other basins ---> **17**

17a. Dorsal fin branched rays modally 9 ---> **18**
17b. Dorsal fin branched rays modally 8 (some counts of 9 but not in Tigris River basin) ---> **19**

18a. Dez River basin of the Tigris River basin = *Capoeta pyragyi*
18b. Karkheh River basin of the Tigris River basin = *Capoeta shajariani*

19a. Karun River basin of the Tigris River basin and Esfahan basin = *Capoeta coadi*
19b. Other basins ---> **20**

20a. Zohreh River basin in Persis basin; dorsal fin branched rays 8 usually = *Capoeta ferdowsii*
20b. Dasht-e Lut, Hamun-e Jaz Murian, Hormuz, Kerman-Na'in, Kor River, Lake Maharlu, Persis (except Zohreh River basin) and Sirjan basins; dorsal fin branched rays 8 or 9 usually = *Capoeta saadii*

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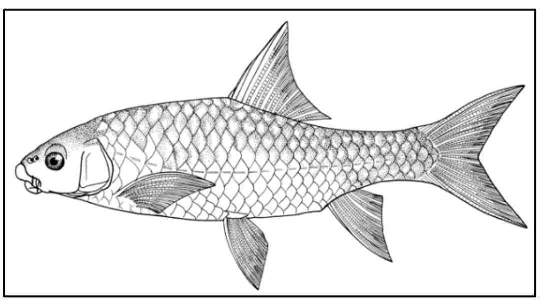
**Key to *Carasobarbus***



*Carasobarbus sublimus*

1a. Lower lip without lobe; one or two pairs of barbels, usually one; attains 45 cm total length; Hormuz, Lake Maharlu, Persis and Tigris River basins = *Carasobarbus luteus*
1b. Distinctive median lower lip lobe; two pairs of barbels; less than 20 cm total length; Persis and Tigris River basins ---> **2**


Median lower lip lobe in
*Carasobarbus sublimus*

2a. Lateral line scales 31-41; total vertebrae 39-40; Tigris River basin = *Carasobarbus kosswigi*
2b. Lateral line scales 24-29; total vertebrae 37-38; Persis and Tigris River basins = *Carasobarbus sublimus*

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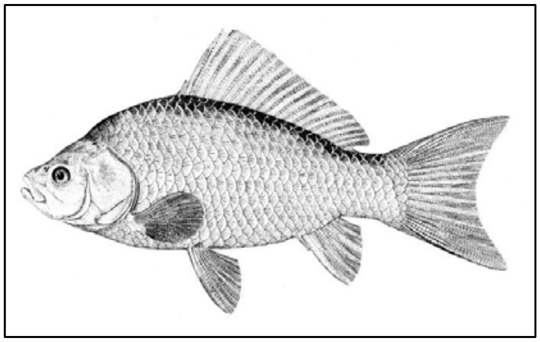
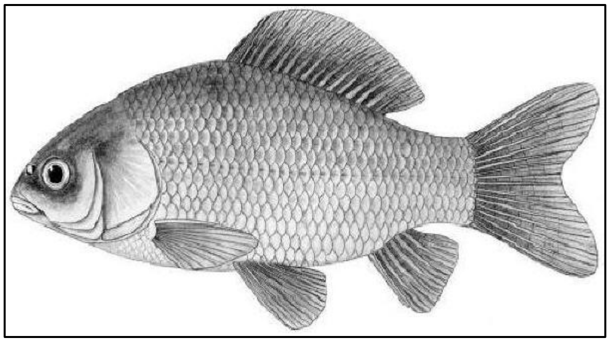
## Key to *Carassius*

Goldfish (usually called *Carassius auratus* and a distinctive red in colour) have been widely introduced in Iran. Established populations lose this typical red colour in the wild. Presence and distribution of other species is uncertain. *C. auratus* and *C. gibelio* are variously treated as synonyms (*auratus* being the domesticated form of *gibelio*), as subspecies of *C. auratus*, or as distinct species. *C. auratus* and *C. gibelio* are morphologically very similar and reliable identification is not possible on morphological characters (Kalous *et al.*, 2013; Halas *et al.*, 2018). The distinct *C. carassius* is reported from Iran but accuracy of identification of this species from records in the literature is uncertain. Khosravi *et al.* (2020) examined material using cytochrome *b* from the Anzali Wetland in Gilan (which was identified as *C. gibelio*), the Hamun-e Saberi in Sistan (*C. auratus*), the Karun River and Shadegan Wetland in Khuzestan (*C. auratus*) and the Siah Palas Stream in Tehran (*C. langsdorfii*), the latter being a new *Carassius* species record. *C. langsdorfii* is also not readily distinguishable on morphology. The following key might separate *C. carassius* from *C. auratus/gibelio*.

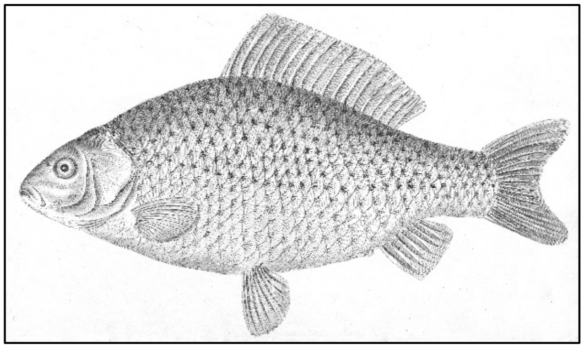
1a. Lateral line scales 21-36, mostly 31 or less; total gill rakers 34-54, size dependent and mostly 39 or more in adults; anal fin branched rays modally 5; snout pointed; dorsal fin spine strong with 10-11 denticles becoming markedly large towards tip; dorsal fin straight or slightly concave; caudal fin deeply forked and sharply lobed; domesticated form red, naturalised form grey-greenish; peritoneum dark; young never with dark spot on caudal peduncle; exotic = *Carassius auratus/gibelio*
1b. Lateral line scales 31-36; total gill rakers 22-35, mostly 31 or less; anal fin branched rays modally 6; snout rounded; dorsal fin spine weak with typically 28-29 denticles; dorsal fin higher for longer and convex; caudal fin bluntly lobed; golden bronze colour; peritoneum light; young usually with dark spot on caudal peduncle; exotic = *Carassius carassius*



*Carassius auratus*



*Carassius carassius*



*Carassius gibelio*

*Carassius langsdorfii*

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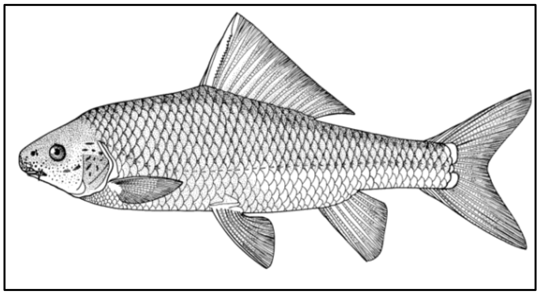
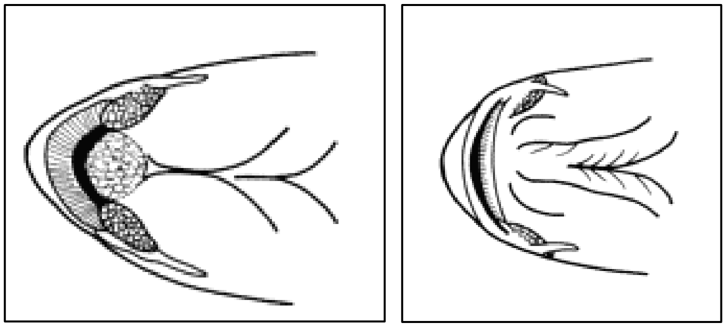
## Key to *Cyprinion*



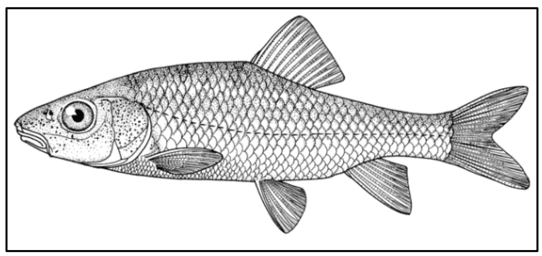
*Cyprinion macrostomus*

1a. Mouth small with large lateral lobes; cartilage forming a tooth-like structure on lower jaw [dorsal fin branched rays 12-16; total gill rakers 9-15]; Persis and Tigris River basins = *Cyprinion kais*

1b. Mouth without large lateral lobes; cartilage on lower jaw arched and not tooth-like ---> **2**

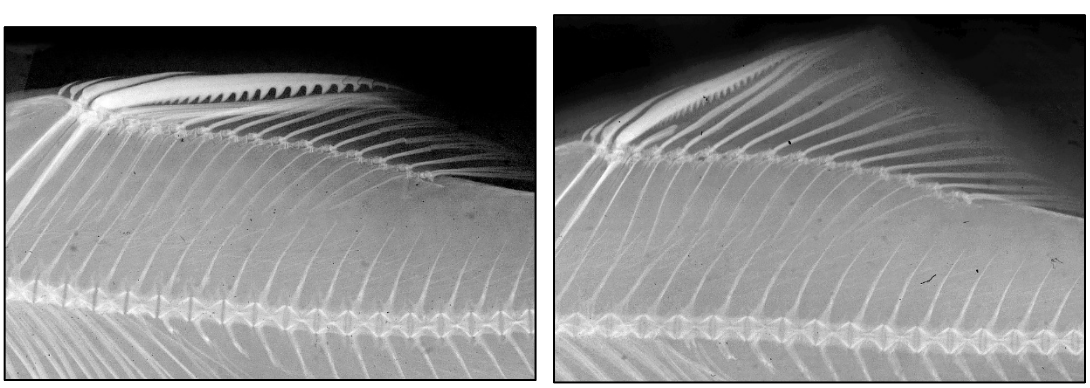

*Cyprinion kais* and *C. macrostomus* ventral heads

2a. Mouth oblique and long in lateral view [dorsal fin branched rays 9-13, mostly 9-10; total gill rakers 11-16]; Hamun-e Jaz Murian, Hormuz and Makran basins = *Cyprinion milesi*
2b. Mouth arched in young, transverse in adults ---> **3**

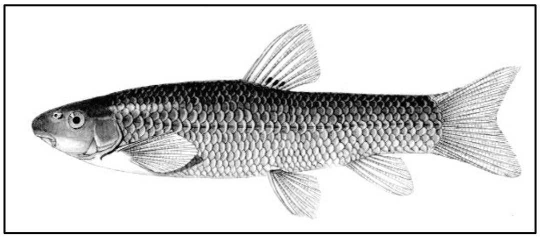

Oblique mouth in *Cyprinion milesi*

3a. Dorsal fin branched rays 9-12, usually 10-11, means 10.0-10.5; Bejestan, Dasht-e Lut, Hamun-e Jaz Murian, Hamun-e Mashkid, Hormuz, Kerman-Na'in, Makran, Sirjan and Sistan basins = *Cyprinion watsoni*
3b. Dorsal fin branched rays 11-17, usually 12-15, means 13.1-13.9; Lake Maharlu, Persis and Tigris River basins ---> **4**

4a. Dorsal fin spine teeth well-developed, even near spine tip; Persis (possibly) and Tigris River basins = C*yprinion macrostomus*
4b. Dorsal fin spine teeth graded in size as near tip and finer, or absent; Lake Maharlu, Persis and Tigris River (possibly) basins = *Cyprinion tenuiradius*


Dorsal fin spine x-rays of *Cyprinion macrostomus* and *Cyprinion tenuiradius*

## Key to *Garra*



*Garra rossica*

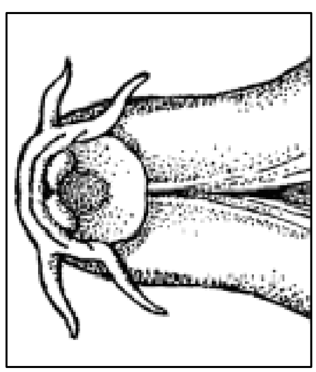
Modified after Esmaeili *et al*. (2016) and Zamani-Faradonbe *et al*. (2021a). Distribution is often key with seven species restricted to a single river or cave.

An undescribed species from the upper reaches of the Kul River drainage in the Hormuz basin is defined by having modally 7 dorsal fin branched rays and 17 branched caudal fin rays. It is not included in this key as some individuals overlap with *G. rufa* to the west and *G. persica* to the east in the combination of these two characters. Molecular data supports recognition of this species but are not field characters.

1a. Hypogean or cave species; body whitish or pink; eyes absent ---> **2**
1b. Epigean or surface species; body brown or grey, usually mottled; eyes present ---> **4**

Hypogean species, *Garra lorestanensis*

2a. Mental disc absent; Tigris River basin in Loven Cave and Tuveh Spring = *Garra typhlops*
2b. Mental disc present ---> **3**



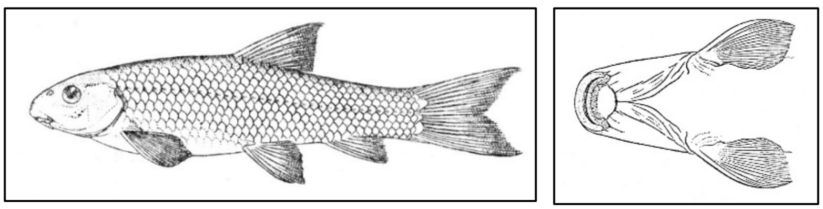
Ventral head with mental
disc in *Garra lorestanensis*

3a. Mental disc elliptical; 28-35 lateral line pores; mouth small and subterminal; Tigris River basin in Loven Cave and Tuveh Spring = *Garra lorestanensis*
3b. Mental disc round; no pores in lateral line; mouth wide and midterminal; Tigris River basin in Tashan Cave = *Garra tashanensis*

4a. Barbels absent; Tang-e-Sarhe Stream, Makran basin = *Garra roseae*
4b. Barbels present --->

5a. One pair of barbels (or two pairs of short barbels in some populations) ---> **6**
5b. Two pairs of barbels ---> **8**

6a. Predorsal mid-line region, breast and belly naked; Dasht-e Lut, Makran, Sistan, and possibly Bejestan and Hamun-e Jaz Murian basins = *Garra nudiventris*
6b. Predorsal mid-line region, breast and belly fully covered by scales or with embedded scales ---> **7**



Naked breast and belly in *Garra nudiventris*

7a. Head length longer than caudal peduncle length and pectoral fin length; Bejestan, Dasht-e Lut, Hamun-e Jaz Murian, Hamun-e Mashkid, Hari River, Makran and Sistan basins = *Garra rossica*
7b. Head length shorter than caudal peduncle length and pectoral fin length; Tigris River basin = *Garra variabilis*

8a. Caudal fin branched rays modally 16 (85.6% for 132 fish, range 15-17); [dorsal fin branched rays 7 (94.8% for 134 fish, range 6-8)]; Hamun-e Jaz Murian, Hamun-e Mashkid, Hormuz and Makran basins = *Garra persica*
8b. Caudal fin branched rays modally 17; [dorsal fin branched rays 7-8] ---> **9**

9a. Dorsal fin branched rays 7; breast and anterior belly naked, or with very small embedded scales, or breast covered by large embedded scales and scales on belly not embedded in skin ---> **10**
9b. Dorsal fin branched rays mostly 8; breast naked or covered by both embedded and fully scaled, belly usually covered by scales ---> **12**

10a. Predorsal midline scaleless; breast and anterior belly naked; Persis basin = *Garra mondica*
10b. Predorsal midline always covered by scales, embedded in skin in some individuals; breast and belly with scales, very small and embedded or large and embedded on breast and not embedded on belly ---> **11**

11a. Predorsal midline always covered by embedded scales; breast and belly with very small, embedded scales; Sartang-e Bijar Spring, Tigris River basin = *Garra amirhosseini*
11b. Predorsal midline usually covered by non-embedded exposed scales; breast covered by large embedded scales and scales on belly not embedded in skin; Meymeh River, Tigris River basin = *Garra meymehensis*

12a. Ab-e Shur, Karun River tributary, Tigris River basin; [breast naked, belly scaled; scales around caudal peduncle 12-13] = *Garra tiam*
12b. Elsewhere ---> **13**

13a. Breast naked (in Beshar River population with hidden scales); Tigris River basin = *Garra gymnothorax*
13b. Breast partly covered by scales; Hormuz, Lake Maharlu, Persis and Tigris River basins = *Garra rufa*

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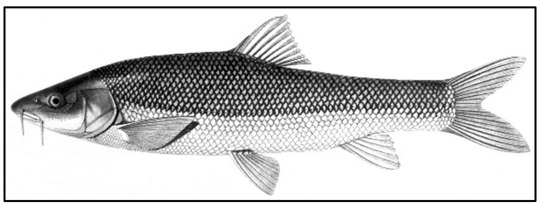
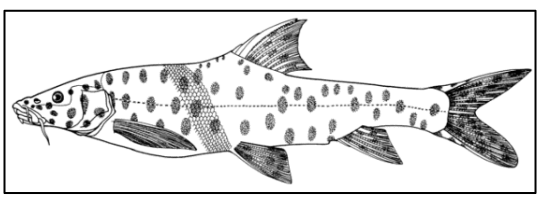
## Key to *Luciobarbus*



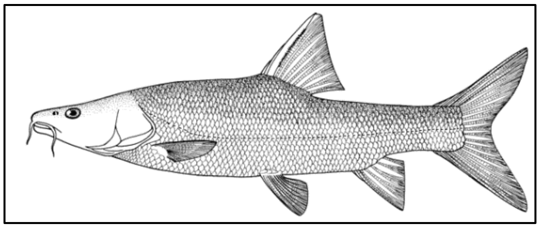
*Luciobarbus capito*

1a. Head, body and fins covered with large dark spots arranged almost in a quincunx (pattern of five); Tigris River basin = *Luciobarbus subquincunciatus*
1b. Without large spots ---> **2**



Spotted *Luciobarbus subquincunciatus*

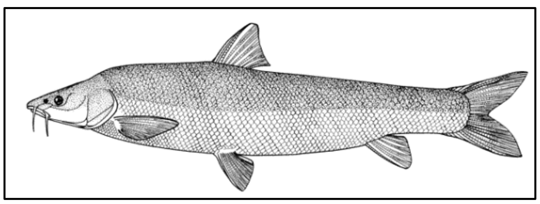
2a. Head elongate, tapering and depressed anteriorly, pike-like, with a long postorbital distance 5.9-7.2 in standard length); adults very large, reputedly over 2 m long; Persis and Tigris River basins = *Luciobarbus esocinus*
2b. Head not as above; not very large, usually to about 1 m or less ---> **3**



Pike-like head in *Luciobarbus esocinus*

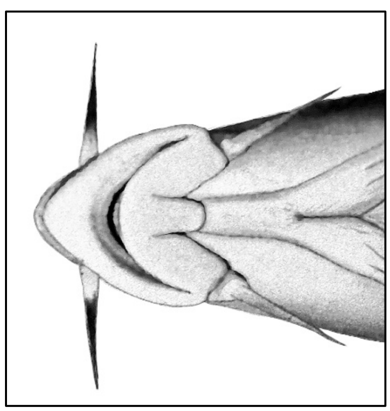
3a. Northern distribution in the Caspian Sea and Hari River basins ---> **4**
3b. Southern and western distribution in the Hormuz, Kor River, Persis and Tigris River basins ---> **7**

4a. Dorsal fin branched rays modally 7; predorsal length shorter than postdorsal length (dorsal fin anterior); [lateral line scales 62-90, usually 65-77; total gill rakers 16-27]; Caspian Sea basin = *Luciobarbus caspius*
4b. Dorsal fin branched rays modally 8; predorsal length equal to or longer than postdorsal length (dorsal fin mid-body) ---> **5**

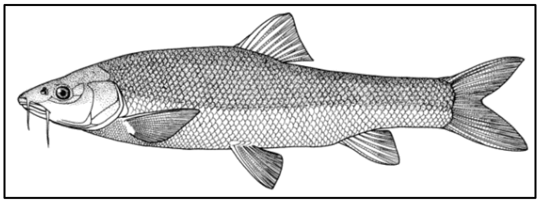


Anterior dorsal fin in *Luciobarbus caspius*

5a. Lateral line scales 74-106, often 85 or more; lower lip usually with three lobes; body shades from dark to light gradually down flank; Caspian Sea basin = *Luciobarbus mursa*
5b. Lateral line scales 51-72; without three lobes to lower lip; upper dark flank usually or sometimes clearly delineated from lighter lower flank; Caspian Sea and Hari River basins ---> **6**



Lower lip with fleshy lobes in
*Luciobarbus mursa*

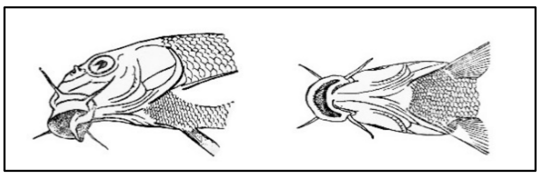


Dark upper and light lower flank in
*Luciobarbus capito*

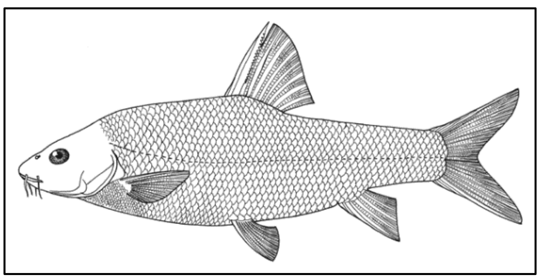
6a. Lips fleshy; Caspian Sea basin = *Luciobarbus capito*
6b. Lips thin; Hari River basin = *Luciobarbus conocephalus*

7a. Total gill rakers 7-14; [lateral line scales 55-69]; Tigris River basin = *Luciobarbus xanthopterus*
7b. Total gill rakers 14 or more, often 18 or more; [lateral line scales 46-59] ---> **8**

8a. Lips markedly fleshy; body moderately deep; fourth major row pharyngeal tooth large and molariform; Persis and Tigris River basins = *Luciobarbus barbulus*
8b. Lips not markedly fleshy; body very deep; fourth major row pharyngeal tooth similar in size to third, not molariform; Persis and Tigris River basins = *Luciobarbus kersin*



Fleshy lips in *Luciobarbus barbulus*



Deep body in *Luciobarbus kersin*

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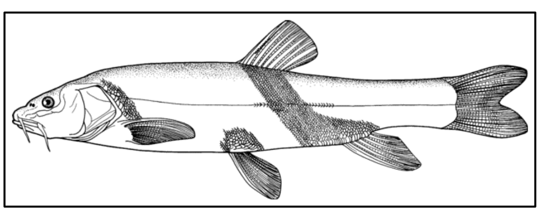
## Key to *Schizothorax*



*Schizothorax pelzami*

1a. Total gill rakers 24-41; pelvic fin branched rays 9-10, usually 9; [mouth terminal and oblique, slightly subterminal in young]; Sistan basin = *Schizothorax zarudnyi*
1b. Total gill rakers 19 or less; pelvic fin branched rays 7-10, usually 8; [mouth terminal, subterminal, u-shaped or arched] ---> **2**

2a. Lateral series scales (next to lateral line) 115-165; [mouth shape very variable]; Sistan basin = *Schizothorax intermedius*
2b. Lateral series scales (next to lateral line) 155-170; [mouth subterminal and arched with horny edge in adults, u-shaped and without horny edge in young]; Dasht-e Kavir and Hari River basins = *Schizothorax pelzami*

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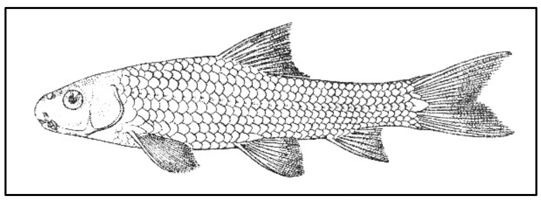
**Key to *Tariqilabeo***



*Tariqilabeo adiscus*

1a. Two pairs of relatively long barbels; rostral barbel 12.2-16.8% of head length; maxillary barbel 5.6-10.5% of head length; total gill rakers 17-25, usually 19-21; scales between anus and anal fin 3-5 (usually 4); Sistan basin = *Tariqilabeo adiscus*
1b. One or two pairs of shorter barbels; rostral barbel 5.5-11.4% of head length; maxillary barbel 1.4-4.1% of head length; total gill rakers 20-25, usually 23-25; scales between anus and anal fin 2-3; Hamun-e Mashkid and Makran basins = *Tariqilabeo diplochilus*

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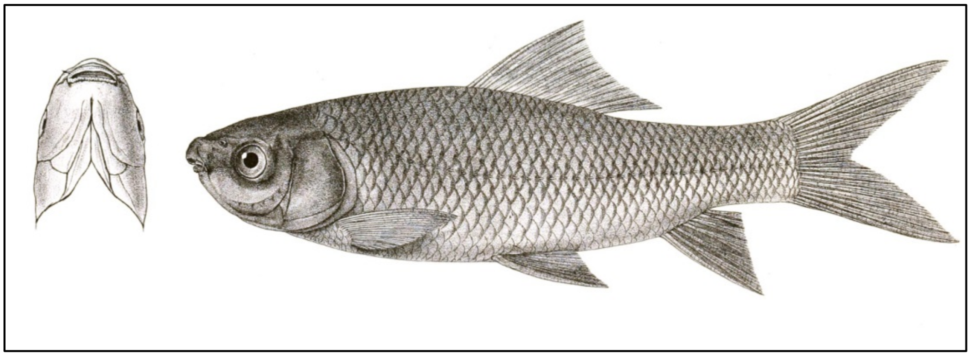
# Checklists

Established exotics such as *Carassius auratus* (combined with the very similar *C. gibelio* and *C. langsdorfii*) and *Cyprinus carpio* are included in the species accounts but potentially-occurring species are not. Note that *Cyprinus carpio* is thought to be native and is also an established exotic. One recently documented exotic is the rohu, *Labeo rohita* (Hamilton, 1822), purchased from fishermen operating in the Karun River and probably escapes from local aquaculture facilities (Eagderi *et al*., 2019). Five fish were caught and this species may become established. Jouladeh-Roudbar *et al*. (2020) gave reasons why they considered this report to be inaccurate and not evidence of naturalisation although the fish is cultivated in various watersheds in Iran.



*Labeo rohita,* after Day (1875-1878).

**Family Cyprinidae**

An asterisk (*) marks Iranian endemics as currently understood. Some species are found in basins shared with neighbouring countries but there are no records of the species outside Iran.

*Arabibarbus grypus* (Heckel, 1843)

*Bangana dero* (Hamilton, 1822)

*Barbus cyri* De Filippi, 1865
**Barbus karunensis* Khaefi, Esmaeili, Geiger and Eagderi, 2017
*Barbus lacerta* Heckel, 1843
**Barbus miliaris* De Filippi, 1863
**Barbus urmianus* Eagderi, Nikmehr, Çiçek, Esmaeili, Vatandoust and Mousavi-Sabet, 2019

**Capoeta aculeata* (Valenciennes, 1844)
**Capoeta anamisensis* Zareian, Esmaeili and Freyhof, 2016
**Capoeta buhsei* Kessler, 1877
*Capoeta capoeta* (Güldenstädt, 1773)
**Capoeta coadi* Alwan, Zareian and Esmaeili, 2016
**Capoeta ferdowsii* Jouladeh-Roudbar, Eagderi, Murillo-Ramos, Ghanavi and Doadrio, 2017
*Capoeta fusca* Nikol'skii, 1897
**Capoeta gracilis* (Keyserling, 1861)
*Capoeta heratensis* (Keyserling, 1861)

*Capoeta kaput* Levin, Prokofiev and Roubenyan, 2019
**Capoeta macrolepis* (Heckel, 1847)
**Capoeta mandica* Bianco and Banarescu, 1982
**Capoeta pyragyi* Jouladeh-Roudbar, Eagderi, Murillo-Ramos, Ghanavi and Doadrio, 2017
*Capoeta razii* Jouladeh-Roudbar, Eagderi, Ghanavi and Doadrio, 2017
**Capoeta saadii* (Heckel, 1847)
**Capoeta shajariani* Jouladeh-Roudbar, Eagderi, Murillo-Ramos, Ghanavi and Doadrio, 2017
*Capoeta trutta* (Heckel, 1843)
*Capoeta umbla* (Heckel, 1843)

*Carasobarbus kosswigi* (Ladiges, 1960)
*Carasobarbus luteus* (Heckel, 1843)
**Carasobarbus sublimus* (Coad and Najafpour, 1997)

*Carassius auratus* (Linnaeus, 1758)
*Carassius gibelio* (Bloch, 1782)
*Carassius langsdorfii* Temminck and Schlegel, 1846

*Cyprinion kais* Heckel, 1843
*Cyprinion macrostomus* Heckel, 1843
*Cyprinion milesi* (Day, 1880)
**Cyprinion tenuiradius* Heckel, 1847
*Cyprinion watsoni* (Day, 1872)

*Cyprinus carpio* Linnaeus, 1758

**Garra amirhosseini* Esmaeili, Sayyadzadeh, Coad and Eagderi, 2016
*Garra gymnothorax* Berg, 1949
**Garra lorestanensis* Mousavi-Sabet and Eagderi, 2016
**Garra meymehensis* Zamani-Faradonbe, Keivany, Dorafshan and Zhang, 2021
**Garra mondica* Sayyadzadeh, Esmaeili and Freyhof, 2015
*Garra nudiventris* (Berg, 1905)
*Garra persica* Berg, 1914
**Garra roseae* Mousavi-Sabet, Saemi-Komsari, Doadrio and Freyhof, 2019
*Garra rossica* (Nikol'skii, 1900)
*Garra rufa* (Heckel, 1843)
**Garra* sp. Kul River, Hormuz basin
**Garra tashanensis* Mousavi-Sabet, Vatandoust, Fatemi and Eagderi, 2016
**Garra tiam* Zamani-Faradonbe, Keivany, Dorafshan and Zhang, 2021
**Garra typhlops* (Bruun and Kaiser, 1944)
*Garra variabilis* (Heckel, 1843)

*Luciobarbus barbulus* (Heckel, 1847)
*Luciobarbus capito* (Güldenstädt, 1773)
*Luciobarbus caspius* (Berg, 1914)
*Luciobarbus conocephalus* (Kessler, 1872)

*Luciobarbus esocinus* Heckel, 1843
*Luciobarbus kersin* (Heckel, 1843)
*Luciobarbus mursa* (Güldenstädt, 1773)
*Luciobarbus subquincunciatus* (Günther, 1868)
*Luciobarbus xanthopterus* Heckel, 1843

*Mesopotamichthys sharpeyi* (Günther, 1874)

*Schizocypris altidorsalis* Bianco and Banarescu, 1982

*Schizopygopsis stolickai* Steindachner, 1866

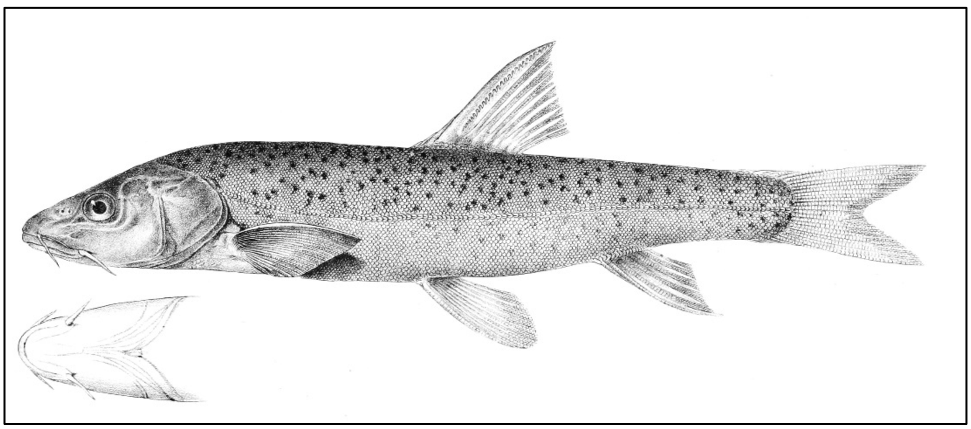
*Schizothorax intermedius* McClelland and Griffith, 1842
*Schizothorax pelzami* Kessler, 1870
*Schizothorax zarudnyi* (Nikol'skii, 1897)

*Tariqilabeo adiscus* (Annandale, 1919)
*Tariqilabeo diplochilus* (Heckel, 1838)

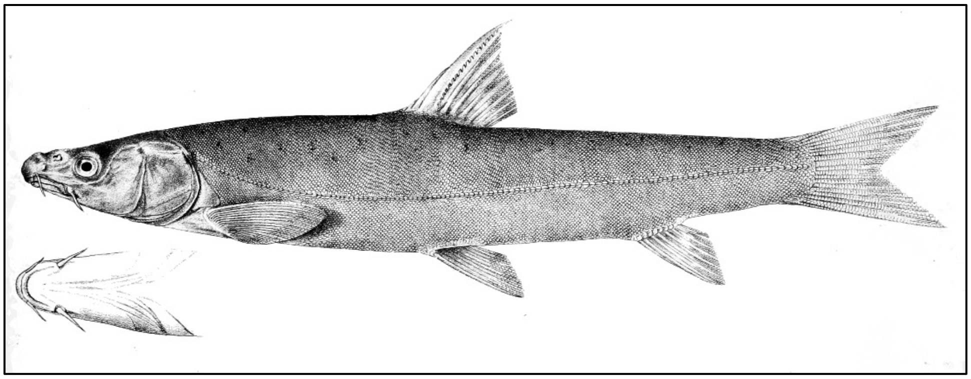
The following species have been recorded in water bodies shared with, or neighbouring, Iran and may eventually be found in Iran. *Bangana dero* was one such species, first recorded from Iran by Esmaeili *et al*. (2013).

In the Helmand River basin of Afghanistan:-

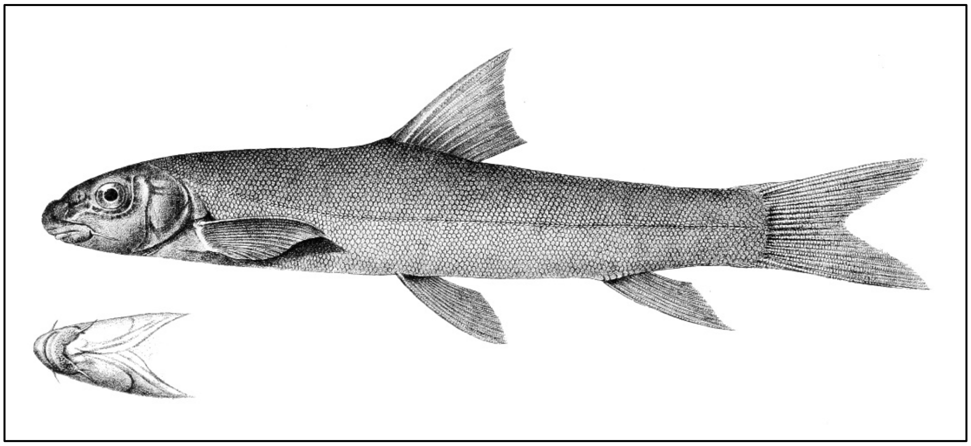
*Schizothorax esocinus* Heckel, 1838
*Schizothorax labiatus* (McClelland, 1842)
*Schizothorax plagiostomus* Heckel, 1838



*Schizothorax esocinus*, after Day (1875-1878).



*Schizothorax labiatus* (as *S. chrysochlorus*), after Day (1875-1878).



*Schizothorax plagiostomus* (as *S. sinuatus*), after Day (1875-1878).

In southwest Pakistan:-

*Bangana gedrosicus (*Zugmayer, 1912) (Mashkel River basin)
*Tariqilabeo macmahoni (*Zugmayer, 1912) (Dasht River basin)

(there are no illustrations of these two species).

## Biodiversity

The carp or cyprinid fauna of Iran comprises 66 native species in 14 genera, plus the exotics *Carassius auratus*, *C. gibelio* and *C. langsdorfii* and potentially other exotics from fish farms, see Eagderi *et al*. (2019). For comparison (using the *Catalog of Fishes*, downloaded 10 October 2018 and references), Pakistan has 66 native species (Mirza, 2003), Turkey has 56 native species of carps (Kuru *et al*., 2014; Çiçek *et al*., 2015; Sungur Birecikligil *et al*., 2017; Çiçek *et al*., 2020), Afghanistan has 32 native species (Coad, 2014), Iraq has 24 native species (Coad, 2010), and the Arabian Peninsula has 20 native species (Freyhof *et al*., 2020).

Carps comprise about 24% of the freshwater ichthyofauna of Iran while minnows (Leuciscidae) comprise about 19% (Esmaeili *et al*., 2017; *Catalog of Fishes*, downloaded 27 September 2018). New species are likely to be found and will be endemics, with a restricted distribution that enhances the biodiversity of a particular drainage basin or ecoregion but has a restricted utility in comparing basins zoogeographically on presence-absence data, unless their genetic relationships also become known.

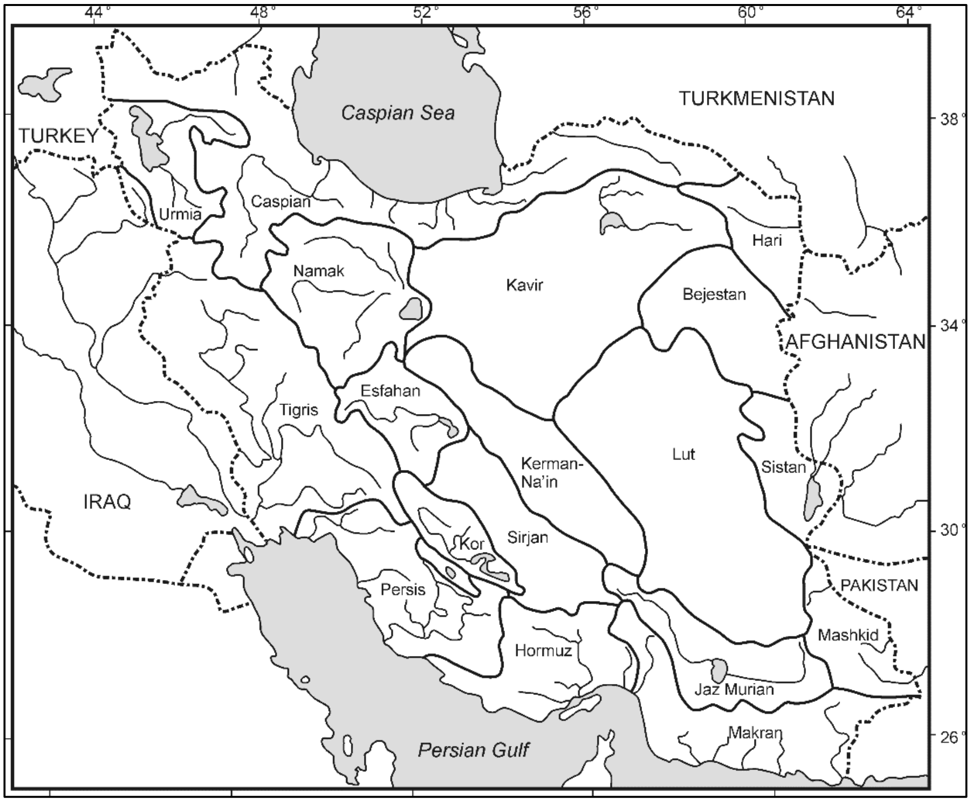
There are 25 species endemic to Iran (37.9% of the carps) (see **Checklist** above). Sixteen of the endemics occur in a single basin. Endemics in the Caspian Sea and Tigris River basins may also be found in adjacent countries with the notable exception of three cave fish species.

The most diverse genera are *Capoeta* (18 species), *Garra* (15) and *Luciobarbus* (9) or 63.6% of the fauna. All other genera have five or less species and six genera are monotypic. No genus is endemic to Iran.

Recent studies have increased the number of carp species known from Iran. In the 100 years of the twentieth century (1900-1999) 22 nominal species/subspecies of Cyprinidae were described from Iran while in the first 20 years of the twenty-first century (2000-2019) 15 were described, 8 of these being in the genus *Capoeta*.

Biodiversity by drainage basins and ecoregions are summarised below.

1) Native species distribution by drainage basins (number of species in parentheses; endemics indicated by *):-




Major drainage basins of Iran.
(the Lake Maharlu basin lies between the Kor River and Persis basins ),
Susan Laurie-Bourque @ Canadian Museum of Nature.

An asterisk (*) marks endemics which here are endemic to the basin and may include waters outside Iran (in the Caspian Sea, Hari River, Sistan and Tigris River basins). An octothorpe (#) marks species requiring confirmation of this distribution.

a) Exorheic basins

Hormuz (12, 2 endemics): *Arabibarbus grypus*, *Barbus lacerta*, **Capoeta anamisensis*, *Capoeta mandica*, *Capoeta saadii*, *Carasobarbus luteus*, *Cyprinion milesi*, *Cyprinion watsoni*, **Garra* sp., *Garra persica*, *Garra rufa*, *Luciobarbus barbulus*.

Makran (7, 1 endemic): *Cyprinion milesi*, *Cyprinion watsoni*, *Garra nudiventris*, *Garra persica*, **Garra roseae*, *Garra rossica*, *Tariqilabeo diplochilus*.

Persis (former Gulf) (18, 1 endemic): *Arabibarbus grypus*, *Barbus lacerta*, **Capoeta ferdowsii*, *Capoeta macrolepis*, *Capoeta mandica*, *Capoeta saadii*, *Capoeta trutta*, *Carasobarbus luteus*, *Carasobarbus sublimus*, *Cyprinion kais*, *Cyprinion macrostomus*, *Cyprinion tenuiradius*, *Garra mondica*, *Garra rufa*, *Luciobarbus barbulus*, *Luciobarbus esocinus*, *Luciobarbus kersin*, *Mesopotamichthys sharpeyi*.

Tigris River (30, 15 endemic): *Arabibarbus grypus*, **Barbus karunensis*, *Barbus lacerta*, **Capoeta coadi*, *Capoeta macrolepis*, *Capoeta mandica*, **Capoeta pyragyi*, **Capoeta*

*shajariani*, *Capoeta trutta*, *Capoeta umbla*, **Carasobarbus kosswigi*, *Carasobarbus luteus*, **Carasobarbus sublimus*, *Cyprinion kais*, *Cyprinion macrostomus*, **Garra amirhosseini*, *Garra gymnothorax*, **Garra lorestanensis*, **Garra meymehensis*, *Garra rufa*, **Garra tashanensis*, **Garra tiam*, **Garra typhlops*, **Garra variabilis*, *Luciobarbus barbulus*, *Luciobarbus esocinus*, *Luciobarbus kersin*, **Luciobarbus subquincunciatus*, **Luciobarbus xanthopterus*, *Mesopotamichthys sharpeyi*.

b) Endorheic basins

Bejestan (3): *Capoeta fusca*, *Cyprinion watsoni*, *Garra rossica*.

Caspian Sea (8, 4 endemic): *Barbus cyri*, *Capoeta capoeta*, **Capoeta kaput*, **Capoeta razii*, *Cyprinus carpio*, **Luciobarbus capito*, **Luciobarbus caspius*, *Luciobarbus mursa*.

Dasht-e Kavir (6): *Barbus miliaris*, *Capoeta aculeata*, *Capoeta buhsei*, *Capoeta fusca*, *Capoeta razii*, *Schizothorax pelzami*.

Dasht-e Lut (5): *Capoeta fusca*, *Capoeta saadii*, *Cyprinion watsoni*, *Garra nudiventris*, *Garra rossica*.

Esfahan (3, 1 endemic): *Barbus lacerta*, *Capoeta coadi*, **Capoeta gracilis*.

Hamun-e Mashkid (6): *Bangana dero*, *#Cyprinion milesi*, *Cyprinion watsoni*, *Garra persica*, *Garra rossica*, *Tariqilabeo diplochilus*.

Hamun-e Jaz Murian (5): *#Capoeta saadii*, *Cyprinion milesi*, *Cyprinion watsoni*, *Garra persica*, *Garra rossica*.

Hari River (7, 1 endemic): *Capoeta fusca*, **Capoeta heratensis*, *Cyprinus carpio*, *Garra rossica*, *Luciobarbus conocephalus*, *Schizothorax intermedius*, *Schizothorax pelzami*.

Kerman-Na'in (5): *Capoeta buhsei*, *#Capoeta macrolepis*, *Capoeta saadii*, *Cyprinion watsoni*, *#Garra persica*.

Kor River (5): *Capoeta macrolepis*, *Capoeta saadii*, *#Carasobarbus luteus*, *Garra rufa*, *Luciobarbus barbulus*.

Lake Maharlu (5): *Barbus lacerta*, *Capoeta saadii*, *Carasobarbus luteus*, *Cyprinion tenuiradius*, *Garra rufa*.

Lake Urmia (4, 1 endemic): *Barbus cyri*, **Barbus urmianus*, *Capoeta capoeta*, *Luciobarbus mursa*.

Namak Lake (3): *Barbus miliaris*, *Capoeta aculeata*, *Capoeta buhsei*.

Sirjan (3): *#Capoeta buhsei*, *Capoeta saadii*, *Cyprinion watsoni*.

Sistan (10, 3 endemic): *Capoeta fusca*, *Cyprinion watsoni*, *Garra nudiventris*, *#Garra persica*, *Garra rossica*, **Schizocypris altidorsalis*, *Schizopygopsis stolickai*, *Schizothorax intermedius*, **Schizothorax zarudnyi*, **Tariqilabeo adiscus*.

Fourteen basins have seven or fewer species and these are endorheic basins or, in the case of the exorheic Makran, remote from other major basins. These basins generally are remote from larger, more diverse basins and centres of speciation and have less diversity in habitats in a desert environment. The Tigris River basin with its diverse habitats and long speciation history has the most species (30), followed by the adjacent Persis (18) and Hormuz (12) basins. Diversity is related to size of the basin, habitat diversity (e.g., the Tigris River basin has major rivers and lakes, streams, ponds, marshes, and altitudinal, temperature and water quality variation), and proximity or remoteness to other, major basins either today or in the recent and distant past (e.g., the latter two to the Tigris River basin), and endorheic or exorheic watercourses. Large rivers, for example, allow migratory behaviour for spawning and physically accommodate larger species. The Sistan basin has the most species of the endorheic basins, attributed in part to the presence of schizothoracines, normally high-altitude species, which entered this lowland via the riverine highway of the Hirmand. The Caspian Sea basin has 8 species and has a long history of connection and isolation from the Black Sea and drainages further west.

Endemics are most evident in the Tigris River basin, comprising 15 of 30 species or 50.0%, and in the Caspian Sea basin comprising 4 of 8 species or 50.0%. Other basins have only 1-4 endemics although a number of these species have a limited distribution in adjacent basins wholly within Iran.

2) Native species distribution in drainage basins (questionable distributions above included, marked by an octothorpe (#)):-

*Arabibarbus grypus* (3): Hormuz, Persis, Tigris River.

*Bangana dero* (1): Hamun-e Mashkid.

*Barbus cyri* (2): Caspian Sea, Lake Urmia.
*Barbus karunensis* (1): Tigris River.
*Barbus lacerta* (5): Esfahan, Hormuz, Lake Maharlu, Persis, Tigris River.
*Barbus miliaris* (2): Dasht-e Kavir, Namak Lake.
*Barbus urmianus* (1): Lake Urmia.

*Capoeta aculeata* (2): Dasht-e Kavir, Namak Lake.
*Capoeta anamisensis* (1): Hormuz.
*Capoeta buhsei* (4): Dasht-e Kavir, Kerman-Na'in, Namak Lake, #Sirjan.
*Capoeta capoeta* (2): Caspian Sea, Lake Urmia.
*Capoeta coadi* (2): Esfahan, Tigris River.
*Capoeta ferdowsii* (1): Persis.
*Capoeta fusca* (5): Bejestan, Dasht-e Kavir, Dasht-e Lut, Hari River, Sistan.
*Capoeta gracilis* (1): Esfahan.
*Capoeta heratensis* (1): Hari River.

*Capoeta kaput* (1): Caspian Sea.
*Capoeta macrolepis* (4): #Kerman-Na'in, Kor River, Persis, Tigris River.
*Capoeta mandica* (3): Hormuz, Persis, Tigris River.
*Capoeta pyragyi* (1): Tigris River.
*Capoeta razii* (2): Caspian Sea, #Dasht-e Kavir.
*Capoeta saadii* (8): Dasht-e Lut, #Hamun-e Jaz Murian, Hormuz, Kerman-Na'in, Kor River, Lake Maharlu, Persis, Sirjan.
*Capoeta shajariani* (1): Tigris River.
*Capoeta trutta* (2): Persis, Tigris River.
*Capoeta umbla* (1): Tigris River.

*Carasobarbus kosswigi* (1): Tigris River.
*Carasobarbus luteus* (5): Hormuz, #Kor River, Lake Maharlu, Persis, Tigris River.
*Carasobarbus sublimus* (2): Persis, Tigris River.

*Cyprinion kais* (2): Persis, Tigris River.
*Cyprinion macrostomus* (2): Persis, Tigris River.
*Cyprinion milesi* (4): #Hamun-e Mashkid, Hamun-e Jaz Murian, Hormuz, Makran.
*Cyprinion tenuiradius* (2): Lake Maharlu, Persis.
*Cyprinion watsoni* (9): Bejestan, Dasht-e Lut, Hamun-e Jaz Murian, Hamun-e Mashkid, Hormuz, Kerman-Na'in, Makran, Sirjan, Sistan.

*Cyprinus carpio* (2): Hari River, Caspian Sea.

*Garra amirhosseini* (1): Tigris River.
*Garra gymnothorax* (1): Tigris River.
*Garra lorestanensis* (1): Tigris River.
*Garra meymehensis* (1): Tigris River.
*Garra mondica* (1): Persis.
*Garra nudiventris* (3): Dasht-e Lut, Makran, Sistan.
*Garra persica* (6): Hamun-e Jaz Murian, Hamun-e Mashkid, Hormuz, #Kerman-Na'in, Makran, #Sistan.
*Garra roseae* (1): Makran.
*Garra rossica* (7): Bejestan, Dasht-e Lut, Hamun-e Jaz Murian, Hamun-e Mashkid, Hari River, Makran, Sistan.
*Garra rufa* (5): Hormuz, Kor River, Lake Maharlu, Persis, Tigris River.
*Garra* sp. (1): Kul River, Hormuz basin.
*Garra tashanensis* (1): Tigris River.
*Garra tiam* (1) : Tigris River.
*Garra typhlops* (1): Tigris River.
*Garra variabilis* (1): Tigris River.

*Luciobarbus barbulus* (4): Hormuz, Kor River, Persis, Tigris River.
*Luciobarbus capito* (1): Caspian Sea.
*Luciobarbus caspius* (1): Caspian Sea.
*Luciobarbus conocephalus* (1): Hari River

*Luciobarbus esocinus* (2): Persis, Tigris River.
*Luciobarbus kersin* (2): Persis, Tigris River.
*Luciobarbus mursa* (2): Lake Urmia, Caspian Sea.
*Luciobarbus subquincunciatus* (1): Tigris River.
*Luciobarbus xanthopterus* (1): Tigris River.

*Mesopotamichthys sharpeyi* (2): Persis, Tigris River.

*Schizocypris altidorsalis* (1): Sistan.

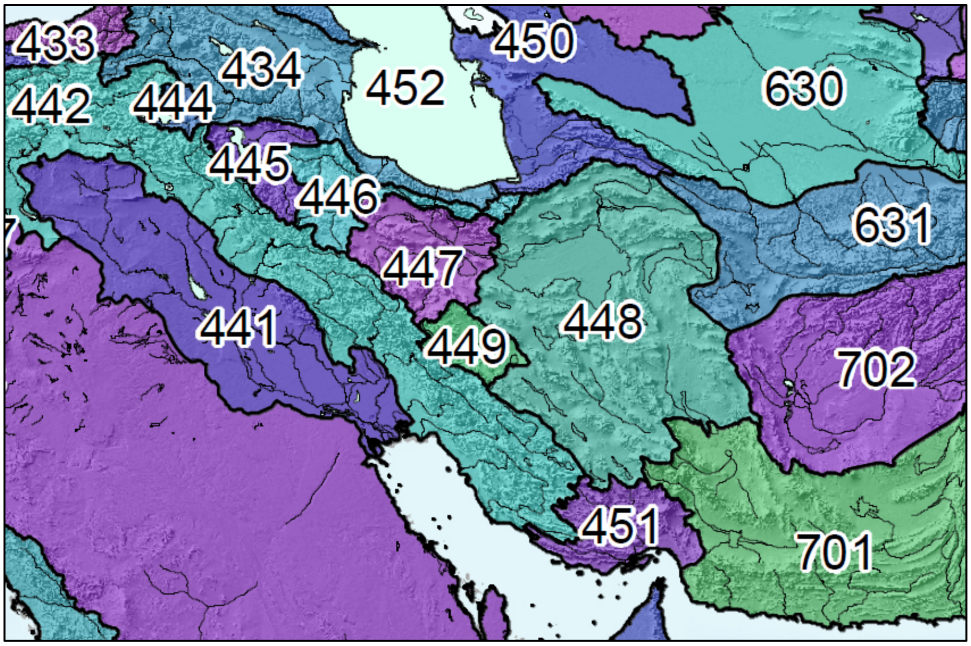
*Schizopygopsis stolickai* (1): Sistan.

*Schizothorax intermedius* (1): Hari River, Sistan.
*Schizothorax pelzami* (2): Dasht-e Kavir, Hari River.
*Schizothorax zarudnyi* (1): Sistan.

*Tariqilabeo adiscus* (1): Sistan.
*Tariqilabeo diplochilus* (2): Hamun-e Mashkid, Makran.

The most widely distributed species in terms of basins is *Cyprinion watsoni* (9 basins), followed by *Capoeta saadii* (8) and *Garra rossica* (7). These are all southeastern species where many of the basins concerned have few other species present. Most species (60 or 93.8%) occur in 1-5 basins and 52 (78.8%) in only 1-2 basins.

3) Ecoregions with native species content. See Abell *et al*. (2008) for descriptions of ecoregions. Records for the ecoregion Caspian Marine (452) are for fish entering brackish water of the nearshore Caspian Sea.



Ecoregions of Iran, after www.feow.org/ and Abell *et al*. (2008)
(note later versions show some minor boundary modifications).

434, Kura-South Caspian: *Barbus cyri*, *Capoeta capoeta*, *Capoeta kaput*, *Capoeta razii*, *Cyprinus carpio*, *Luciobarbus capito*, *Luciobarbus caspius*, *Luciobarbus mursa*.

441, Lower Tigris and Euphrates: *Arabibarbus grypus*, *Barbus lacerta*, *Capoeta macrolepis*, *Capoeta pyragyi*, *Capoeta shajariani*, *Capoeta trutta*, *Capoeta umbla*, *Carasobarbus kosswigi*, *Carasobarbus luteus*, *Cyprinion kais*, *Cyprinion macrostomus*, *Garra amirhosseini*, *Garra gymnothorax*, *Garra rufa*, *Garra variabilis*, *Luciobarbus barbulus*, *Luciobarbus esocinus*, *Luciobarbus kersin*, *Luciobarbus subquincunciatus*, *Luciobarbus xanthopterus*, *Mesopotamichthys sharpeyi*.

442, Upper Tigris and Euphrates: *Arabibarbus grypus*, *Barbus karunensis*, *Barbus lacerta*, *Capoeta coadi*, *Capoeta ferdowsii*, *Capoeta macrolepis*, *Capoeta mandica*, *Capoeta pyragyi*, *Capoeta saadii*, *Capoeta shajariani*, *Capoeta trutta*, *Capoeta umbla*, *Carasobarbus kosswigi*, *Carasobarbus luteus*, *Carasobarbus sublimus*, *Cyprinion kais*, *Cyprinion macrostomus*, *Cyprinion tenuiradius*, *Garra gymnothorax*, *Garra lorestanensis*, *Garra meymehensis*, *Garra mondica*, *Garra rufa*, *Garra tashanensis*, *Garra tiam*, *Garra typhlops*, *Garra variabilis*, *Luciobarbus barbulus*, *Luciobarbus esocinus*, *Luciobarbus kersin*, *Luciobarbus subquincunciatus*, *Luciobarbus xanthopterus*, *Mesopotamichthys sharpeyi*.

445, Orumiyeh (= Urmia): *Barbus cyri*, *Barbus urmianus*, *Capoeta capoeta*, *Luciobarbus mursa*.

446, Caspian Highlands: *Barbus cyri*, *Capoeta razii*, *Luciobarbus capito*, *Luciobarbus mursa*.

447, Namak: *Barbus miliaris*, *Capoeta aculeata*, *Capoeta buhsei*.

448, Kavir and Lut Deserts: *Barbus miliaris*, *Capoeta aculeata*, *Capoeta buhsei*, *Capoeta fusca*, *Capoeta macrolepis*, *Capoeta razii*, *Capoeta saadii*, *Cyprinion watsoni*, *Garra nudiventris*, *Garra persica*, *Garra rossica*, *Schizothorax pelzami*.

449, Esfahan: *Barbus lacerta*, *Capoeta coadi*, *Capoeta gracilis*.

450, Turan Plain: *Barbus cyri*, *Capoeta razii*, *Cyprinus carpio*, *Luciobarbus capito*, *Luciobarbus caspius*, *Luciobarbus mursa*.

451, Northern Hormuz Drainages: *Capoeta anamisensis*, *Capoeta mandica*, *Capoeta saadii*, *Cyprinion milesi*, *Cyprinion watsoni*, *Garra persica*, *Garra rufa*, *Garra* sp.

452, Caspian Marine: *Cyprinus carpio*, *Luciobarbus capito*, *Luciobarbus caspius*, *Luciobarbus mursa*.

631, Upper Amu Darya: *Capoeta fusca*, *Capoeta heratensis*, *Cyprinus carpio*, *Garra rossica*, *Luciobarbus conocephalus*, *Schizothorax intermedius*, *Schizothorax pelzami*.

701, Baluchistan: *Bangana dero*, *Capoeta saadii*, *Cyprinion milesi*, *Cyprinion watsoni*, *Garra nudiventris*, *Garra persica*, *Garra roseae*, *Garra rossica*, *Tariqilabeo diplochilus*.

702, Helmand-Sistan: *Capoeta fusca*, *Cyprinion watsoni*, *Garra nudiventris*, *Garra persica*, *Garra rossica*, *Schizocypris altidorsalis*, *Schizopygopsis stolickai*, *Schizothorax intermedius*, *Schizothorax zarudnyi*, *Tariqilabeo adiscus*.

The ecoregion with the most species is the Upper Tigris and Euphrates with 33 species (50.0% of species) followed by the Lower Tigris and Euphrates with 21 species (32.8%). These represent large areas with diverse habitats. Other ecoregions have 3 to 12 species. The Kavir and Lut Deserts ecoregion has 12 species (18.8%) but, being centrally located, borders on nine other regions. Helmand-Sistan has 11 species (17.2%), diversity being due in part to four schizothoracine fishes. All ecoregions have cyprinids.

4) Native species distribution in ecoregions, presented in numerical order as above:-

*Arabibarbus grypus*: Lower Tigris and Euphrates, Upper Tigris and Euphrates, Northern Hormuz Drainages.

*Bangana dero*: Baluchistan.

*Barbus cyri*: Kura-South Caspian, Orumiyeh (= Urmia), Caspian Highlands, Turan Plain.
*Barbus karunensis*: Upper Tigris and Euphrates.
*Barbus lacerta*: Lower Tigris and Euphrates, Upper Tigris and Euphrates, Esfahan, Northern Hormuz Drainages.
*Barbus miliaris*: Namak, Kavir and Lut Deserts.
*Barbus urmianus*: Orumiyeh (= Urmia).

*Capoeta aculeata*: Namak, Kavir and Lut Deserts.

*Capoeta anamisensis*: Northern Hormuz Drainages.
*Capoeta buhsei*: Namak, Kavir and Lut Deserts, Esfahan.
*Capoeta capoeta*: Kura-South Caspian, Orumiyeh (= Urmia).
*Capoeta coadi*: Upper Tigris and Euphrates, Esfahan.
*Capoeta ferdowsii*: Upper Tigris and Euphrates.
*Capoeta fusca*: Kavir and Lut Deserts, Upper Amu Darya, Helmand-Sistan.
*Capoeta gracilis*: Esfahan.
*Capoeta heratensis*: Upper Amu Darya.
*Capoeta kaput*: Kura-South Caspian.
*Capoeta macrolepis*: Lower Tigris and Euphrates, Upper Tigris and Euphrates, Kavir and Lut Deserts.
*Capoeta mandica*: Upper Tigris and Euphrates, Northern Hormuz Drainages.
*Capoeta pyragyi*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Capoeta razii*: Kura-South Caspian, Caspian Highlands, Kavir and Lut Deserts, Turan Plain.
*Capoeta saadii*: Upper Tigris and Euphrates, Kavir and Lut Deserts, Northern Hormuz Drainages, Baluchistan.
*Capoeta shajariani*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Capoeta trutta*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Capoeta umbla*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.

*Carasobarbus kosswigi*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Carasobarbus luteus*: Lower Tigris and Euphrates, Upper Tigris and Euphrates, Northern Hormuz Drainages.
*Carasobarbus sublimus*: Upper Tigris and Euphrates.

*Cyprinion kais*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Cyprinion macrostomus*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Cyprinion milesi*: Northern Hormuz Drainages, Baluchistan.
*Cyprinion tenuiradius*: Upper Tigris and Euphrates.
*Cyprinion watsoni*: Kavir and Lut Deserts, Northern Hormuz Drainages, Baluchistan, Helmand-Sistan.

*Cyprinus carpio*: Kura-South Caspian, Turan Plain, Caspian Marine, Upper Amu Darya.

*Garra amirhosseini*: Lower Tigris and Euphrates.
*Garra gymnothorax*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Garra lorestanensis*: Upper Tigris and Euphrates.
*Garra meymehensis*: Upper Tigris and Euphrates.
Garra *mondica*: Upper Tigris and Euphrates.
*Garra nudiventris*: Kavir and Lut Deserts, Baluchistan, Helmand-Sistan.
*Garra persica*: Kavir and Lut Deserts, Northern Hormuz Drainages, Baluchistan, Helmand-Sistan.
*Garra roseae*: Baluchistan.
*Garra rossica*: Kavir and Lut Deserts, Upper Amu Darya, Baluchistan, Helmand-Sistan.
*Garra rufa*: Lower Tigris and Euphrates, Upper Tigris and Euphrates, Northern Hormuz Drainages.

*Garra* sp.: Northern Hormuz Drainages.
*Garra tashanensis*: Upper Tigris and Euphrates.
*Garra tiam*: Upper Tigris and Euphrates.
*Garra typhlops*: Upper Tigris and Euphrates.
*Garra variabilis*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.

*Luciobarbus barbulus*: Lower Tigris and Euphrates, Upper Tigris and Euphrates, Northern Hormuz Drainages.
*Luciobarbus capito*: Kura-South Caspian, Caspian Highlands, Turan Plain, Caspian Marine.
*Luciobarbus caspius*: Kura-South Caspian, Turan Plain, Caspian Marine.
*Luciobarbus conocephalus*: Upper Amu Darya.
*Luciobarbus esocinus*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Luciobarbus kersin*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Luciobarbus mursa*: Kura-South Caspian, Orumiyeh (= Urmia), Caspian Highlands, Turan Plain, Caspian Marine.
*Luciobarbus subquincunciatus*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.
*Luciobarbus xanthopterus*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.

*Mesopotamichthys sharpeyi*: Lower Tigris and Euphrates, Upper Tigris and Euphrates.

*Schizocypris altidorsalis*: Helmand-Sistan.

*Schizopygopsis stolickai*: Helmand-Sistan.

*Schizothorax intermedius*: Upper Amu Darya, Helmand-Sistan.
*Schizothorax pelzami*: Kavir and Lut Deserts, Upper Amu Darya.
*Schizothorax zarudnyi*: Helmand-Sistan.

*Tariqilabeo adiscus*: Helmand-Sistan.
*Tariqilabeo diplochilus*: Baluchistan.

The species are found in one to five ecoregions with *Luciobarbus mursa* the only one in five ecoregions. Species in three to five ecoregions (18 or 28.1%) are mostly those associated with the Caspian Sea in northern Iran and Tigris River and adjacent areas in southwestern Iran, areas of diverse habitat. Twenty-five species are found in a single ecoregion (37.9%), 23 in two ecoregions (35.9%), eight in three ecoregions (12.5%) and nine in four ecoregions (14.1%).

## Species Accounts

Much earlier literature on Cyprinidae has a catchall genus *Barbus*, with many species now assigned to other genera namely *Arabibarbus*, *Carasobarbus*, *Luciobarbus* and *Mesopotamichthys*. Readers consulting older literature should be aware that species may appear under these older genera. Species biology discussed in this text may well appear under the more recent name, not the older one that appears in the literature source.

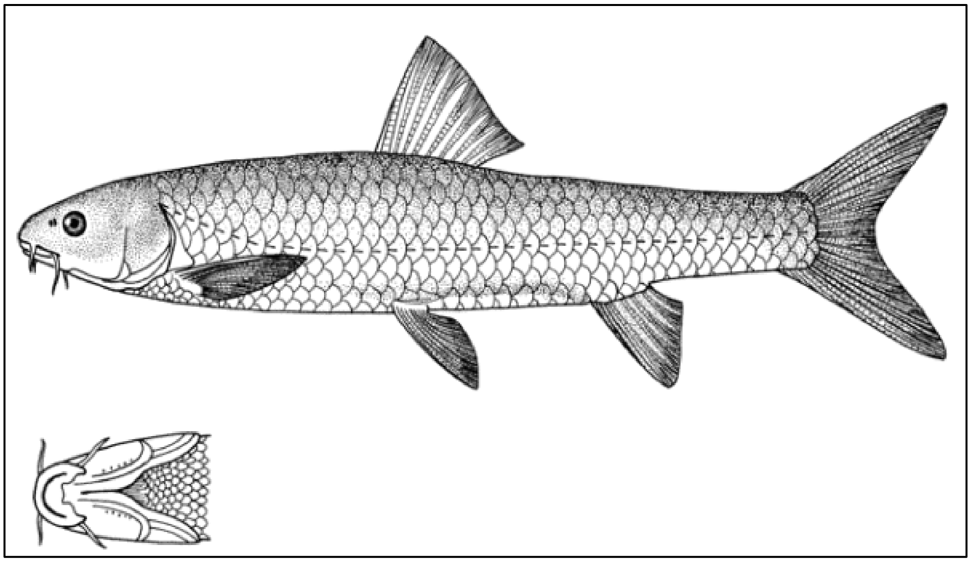
The cyprinids or barbs are found in Africa, Asia and Europe and number about 1,695 species (*Catalog of Fishes*, downloaded 31 January 2019). The family is defined by molecular characters and by some morphological characters in combination and with exceptions between genera and across families in the Cyprinoidei. Generally, carps in Iran have barbels (one to two pairs) but these are sometimes absent (e.g., *Mesopotamichthys*, *Garra roseae*), fleshy or highly modified lips (e.g., *Bangana*, *Luciobarbus*) or arched mouths with a horny lower lip (e.g., *Capoeta*, *Cyprinion*), some have a ventral adhesive disc variably developed on the chin (e.g., *Garra*) or papillations (e.g., *Tariqilabeo*), a rostral cap is often present, the last dorsal fin unbranched ray is often "spiny" with denticles or teeth (spineless in *Tariqilabeo,* spine but no denticles in *Arabibarbus*, for example), the dorsal fin often has 8 branched rays (but as many as 23 rays in *Cyprinus*), the anal fin is usually small (5-7 branched rays), an anal fin spine is rarely present (e.g., *Carassius* and *Cyprinus*), scales are small to large (25-104 in the lateral line), enlarged scales may be present around the vent and anal fin (e.g., *Schizocypris*, *Schizopygopsis*, *Schizothorax*), some species are very large (e.g., *Luciobarbus esocinus* to 2.4 m and 150 kg), some are scaleless and blind cave fish (three species in the genus *Garra*), pharyngeal teeth are in one to three rows (usually the latter with a formula 2,3,4 or 5-5 or 4, 3,2), and some are polyploids (e.g., hexaploids, 2n = 150, in *Capoeta*, and in schizothoracines).

### Genus *Arabibarbus*
Borkenhagen, 2014

This genus has three species, two in Yemen, and one in the Tigris-Euphrates and the Orontes River basins and southern Iran. The genus is characterised by a medium to large body size, the last dorsal fin unbranched ray is ossified as a smooth spine, the dorsal fin has 8 branched rays modally and the anal fin has 5 branched rays modally, scales are large and shield-shaped with numerous parallel radii, pharyngeal tooth count is 2,3,5-5,3,2 and teeth are hooked at the tip, and there are two pairs of barbels (Borkenhagen, 2017b). It differs from some other genera such as *Carasobarbus* which has 9-10 branched dorsal rays, 6 anal fin branched rays and a deeper body, and from *Mesopotamichthys* which lacks barbels. Borkenhagen (2014) found this genus to form a monophyletic group in the cytochrome *b* phylogram. These fishes are probably hexaploids, as are the two other Torini in Iran, *Carasobarbus* and *Mesopotamichthys*, resulting from hybridisation between tetraploid Torini and diploid *Cyprinion*-like ancestors (Borkenhagen, 2017b). The divergence between *Arabibarbus*, *Carasobarbus* and *Mesopotamichthys* was not resolved by Borkenhagen (2017b) but probably happened in the late Miocene or Pliocene.

Much of the past literature on this genus appeared under *Barbus* (*q.v.*) and some under *Tor* Gray, 1834.

### *Arabibarbus grypus*
(Heckel, 1843)

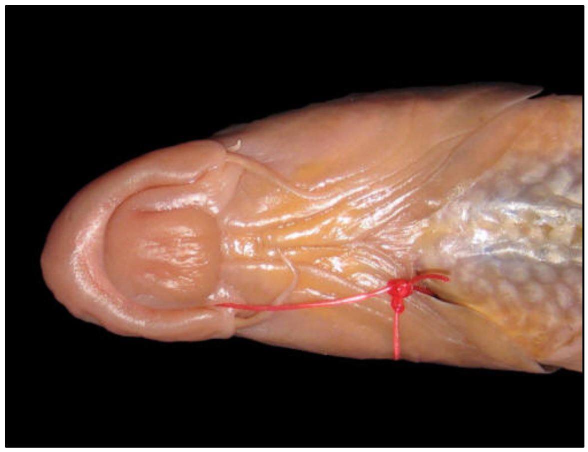


*Arabibarbus grypus*
Susan Laurie-Bourque @ Canadian Museum of Nature.

*Arabibarbus grypus*, Ilam, Kangir River, Tigris River basin, Atabak Mahjoorazad.

*Arabibarbus grypus*, ventral head, Ilam, Kangir River, Tigris River basin, Atabak Mahjoorazad.

*Arabibarbus grypus*, Ilam, Changuleh River, Tigris River basin, Atabak Mahjoorazad.



*Arabibarbus grypus*, ventral head, Ilam,
Changuleh River, Tigris River basin,
Atabak Mahjoorazad.

*Arabibarbus grypus*, Iran, 55 cm
(CC BY 3.0, cropped, Seyedahmadreza Hashemi).

**Common names.** Shirbot, shaboot, shebhe or shebeh shirbot, shilbot, shirbod or shirbut (see below for possible meaning; shebeh means resembling), sas or sos mahi (meaning of sas and sos unknown but referring to "*Barbus*"), sorkheh (= reddish, a local name in the Zohreh River - J. Gh. Marammazi, pers. comm., 1995), rumi (not heard of in Khuzestan), night touring fish (for *kotschyi* after Vali-ollahi (2019)).

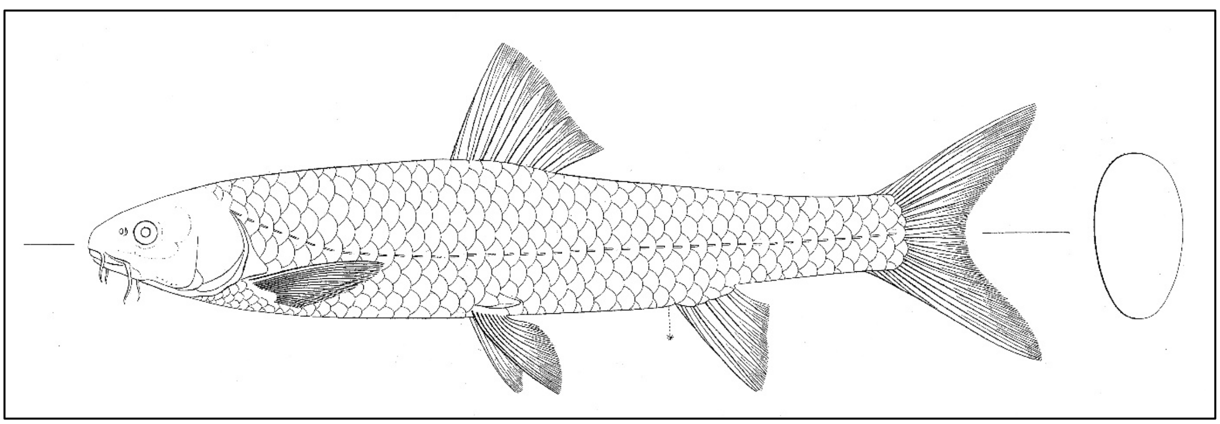
[Shabout, sahabbout, shabbot and shabbut (perhaps from verb root sh-b-t, to beat or knock) and hamrawi (or humrawi, meaning reddish) (Mikaili and Shayegh, 2011)), all in Arabic; Şaput and şabot in Turkish (Çiçek *et al*., 2020); large scaled barb, Tigris barbel].

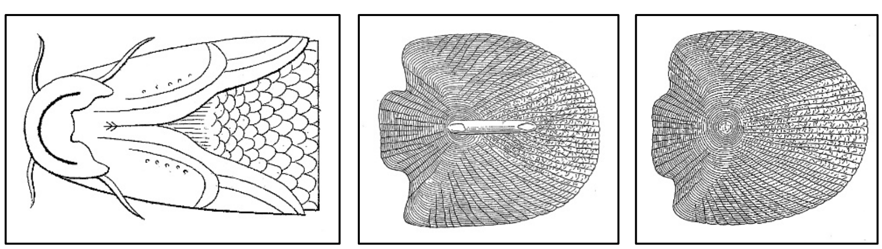
**Systematics.** Howes (1987) placed this species outside the genus *Barbus sensu stricto* as defined by him because it has the non-elongate lachrymal bone with a sensory canal running

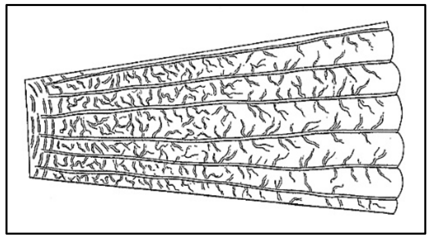
along the antero-dorsal border, a derived condition. Karaman (1971) and Ekmekçi and Banarescu (1998) placed it in the genus *Tor* (see *Barbus* below) and it was thought to belong in *Naziritor* Mirza and Javed, 1985 (M. R. Mirza, pers. comm., 6 December 2003). Al-Hassan (1984) looked at several "*Barbus*" species and found the electropherogram of this species to be distinctive, perhaps indicating that molecular studies could resolve the relationships of this species. This distinction was reiterated by Jawad (2003a). See above under the genus for current placement.

Karami Nasab *et al*. (2014) found that allelic diversity and genetic variation in fish from the Dez and Karun rivers was at a favourable level and that the populations were separate from each other. Abasi Dehkord *et al*. (2018) used the COI gene and concluded this species affinities lie with oriental species such as *Tor* and is closely related to *Mesopotamichthys sharpeyi*. Parmaksız and Şeker (2018) described the genetic diversity of this species in the Tigris and Euphrates rivers of Turkey using partial cytochrome *b* sequences.

The type locality of *Barbus Grypus* is "Tigris bei Mossul" (Heckel, 1843b) and Krupp (1985c) recorded a syntype (dried) from the Naturhistorisches Museum Wien (formerly NMW) now in the Senckenberg Museum Frankfurt under SMF 2613, 37.5 cm standard length. One syntype is in the Museum für Naturkunde, Universität Humboldt, Berlin (ZMB 8788, not located February 2006). One syntype is in Vienna under NMW 54160 (81.0 mm standard length, Ichthyology Type Database, NMW, downloaded 9 July 2016), two are under NMW 54161 (280.9-318.9 mm total length as measured by me), and one is under NMW 91023 (510.0 mm standard length, Ichthyology Type Database, NMW, downloaded 9 July 2016) (Eschmeyer *et al*., 1996). The catalogue in Vienna listed three fish in spirits and two fish stuffed.

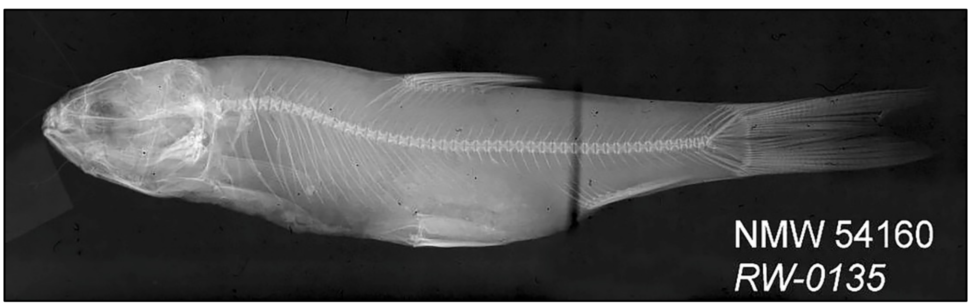






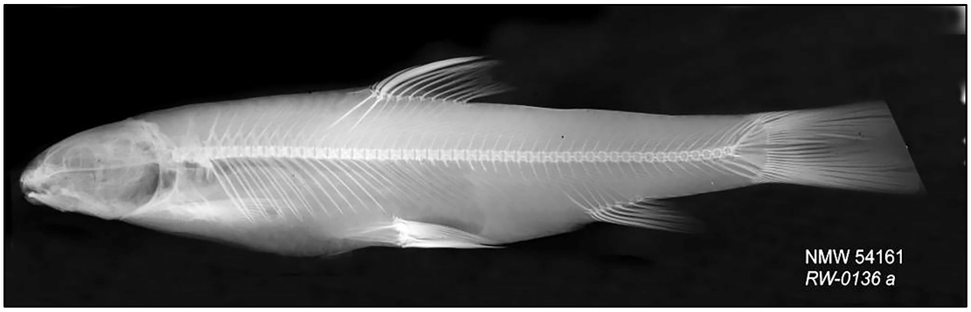
*Barbus grypus*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Barbus grypus*, syntype, NMW 54160, Naturhistorisches Museum Wien.



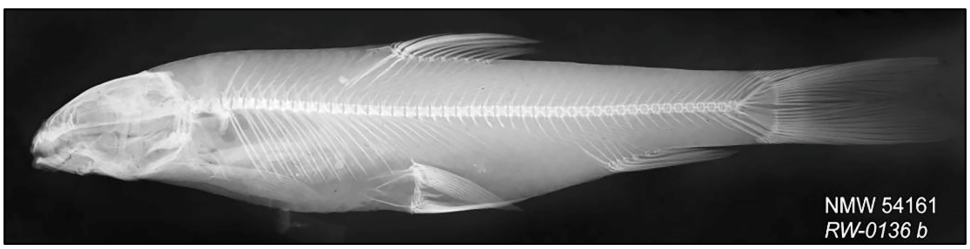

*Barbus grypus*, syntype, NMW 54160, Naturhistorisches Museum Wien.

*Barbus grypus*, syntype, NMW 54161, Naturhistorisches Museum Wien.




*Barbus grypus*, syntype, NMW 54161, Naturhistorisches Museum Wien.

*Barbus grypus*, syntype, NMW 54161, Naturhistorisches Museum Wien.

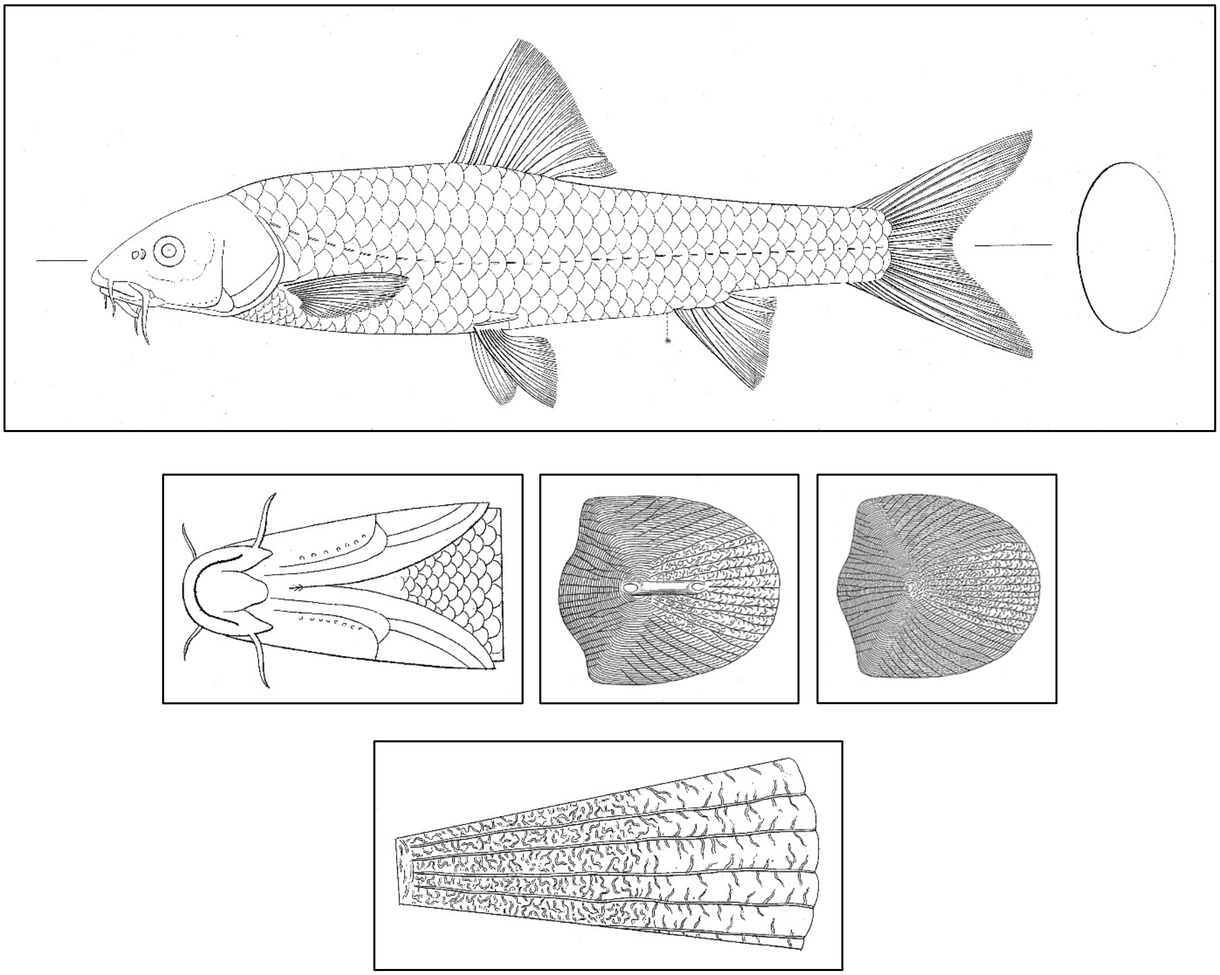



*Barbus grypus*, syntype, NMW 54161, Naturhistorisches Museum Wien.

*Barbus grypus*, syntype, NMW 91023, Naturhistorisches Museum Wien.

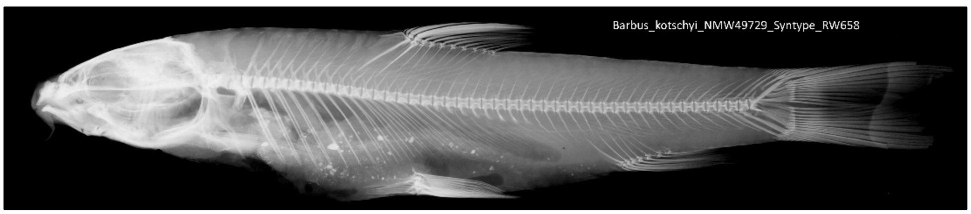
*Labeobarbus Kotschyi* Heckel, 1843 described from the "Tigris bei Mossul" has long been regarded as a synonym although Valiallahi (2000) and Vali-ollahi (2019) resurrected this

species based on morphology of the head (head length, mouth form, fleshy lobe). Krupp (1985c) recorded a syntype from the Naturhistorisches Museum Wien under NMW 49729 (188.8 mm standard length as measured by me). A dried specimen, NMW 59462, is also a syntype. Eschmeyer *et al*. (1996) also listed another syntype, NMW 91022. The catalogue in Vienna listed one fish in spirits and two fish stuffed, as illustrated below.



*Labeobarbus kotschyi*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

*Labeobarbus kotschyi*, syntype, NMW 49729, Naturhistorisches Museum, Wien.




*Labeobarbus kotschyi*, syntype, NMW 49729, Naturhistorisches Museum, Wien.

*Labeobarbus kotschyi*, syntype, NMW 59462, Naturhistorisches Museum, Wien.

*Labeobarbus kotschyi*, syntype, NMW 91022, Naturhistorisches Museum, Wien.

**Key characters.** This species is identified by having two pairs of barbels, a strong, smooth spine in the dorsal fin, 8 dorsal fin branched rays and 5 anal fin branched rays, and less than 45 scales in the lateral line.

**Morphology.** The body is rounded, shallow and elongate, deepest in front of the dorsal fin. The profile in front of the dorsal fin is straight to slightly convex, sometimes with a shallow notch at the rear head, and the head profile is straight to slightly convex. The caudal peduncle is compressed and moderately deep. The forehead is more rounded than in type material of *kotschyi*, although *kotschyi* types are smaller than *grypus* types that may account for this distinction. The mouth is inferior, horseshoe-shaped and has fleshy lips. The median lobe of the lower lip is well-developed in some individuals (such specimens were described as *kotschyi* - this form is rare in Khuzestan according to N. Najafpour (pers. comm., 1995), and intermediates can be seen) but not in others (*grypus*) (Karaman, 1971). The median lobe may extend back almost as far as the level of the rear margin of the lower lip or be distinctive with free lateral and rear margins but only extend back one third of this distance. The much fleshier lip structure in *kotschyi* (the upper lip can be well-developed and reflexed for example) may be a form of hypertrophy seen in other cyprinoid fishes (see Roberts and Khaironizam (2008) for further discussions on this feature). The last dorsal fin unbranched ray is smooth and spine-like, with sharp edges but no serrations although serrations are weakly developed in young fish. Barbels are thin, elongate and about equal in length. The anterior barbel may reach the anterior eye margin and the posterior barbel may reach as far as beyond the posterior eye margin. The dorsal fin margin is emarginate and the dorsal fin origin is slightly anterior to or over the pelvic fin origin. The depressed dorsal fin tip is remote from the anal fin origin level. The caudal fin is deeply forked with rounded tips. The anal fin margin is straight and the fin does not reach back to the caudal fin base when appressed. The pelvic fin margin is rounded to straight and the fin tip is remote from the anus. The pectoral fin margin is rounded and the fin tip is remote from the pelvic fin origin.

*Arabibarbus grypus*, 267.2 mm standard length,
with reflexed upper lip, Iraq, CMNFI 1993-0164,
Brian W. Coad.

Ali *et al*. (1981) found differences in morphology for fish from Al-Therthar Dam and the Tigris River in Iraq, not by locality but by habitat type.

Dorsal fin unbranched rays 3-4, modally 4, branched rays 7-9, modally 8, anal fin unbranched rays 3-4, modally 3, branched rays 4-6, modally 5, pectoral fin branched rays 13-

18, and pelvic fin branched rays 7-8, usually 8. Lateral line scales 32-44. A pelvic axillary scale is present. Scale shape is elongate with a rounded posterior margin that merges with the dorsal and ventral rounded margins. The anterior margin has a rounded centre with an indentation above and below, sometimes quite marked. The anterior scale corners are rounded. Scales have a subcentral anterior, or almost central, focus, numerous fine circuli and many radii on all fields with the exposed part of the scale tubercular. Total gill rakers number 16-22. Krupp (1985c) cites 13-17 gill rakers, presumably lower arch ones only. Gill rakers reach the second raker below or beyond when appressed, with large tubercles or branches on the inner surface in two rows alternating left and right. Pharyngeal teeth are 2,3,4-4,3,2 in some literature, but see below, anterior teeth rounded, the most anterior one small and blunt, posterior ones spatulate with hooked tips. The gut is coiled with two anterior and two posterior loops. Total vertebrae number 44-47 (Howes, 1987), 43-45 (Jawad, 1975) or 46-50 (see below). The syntypes of *Barbus grypus*, NMW 54160 and 54161, have 47(1) and 48(2) total vertebrae. The syntype of *Labeobarbus kostchyi*, NMW 49729, has 48 total vertebrae.

Basir *et al*. (2011, 2012) detailed skin histomorphology and histometry for the head, dorsal fin base and caudal peduncle. Khaksary Mahabady *et al*. (2014) studied the anatomy and histology of the gill in this species, generally finding it similar to other cyprinoids, as was the kidney anatomy and histology in other studies (Khaksary Mahabady *et al*., 2014; Morovvati *et al*., 2017). Malekpouri *et al*. (2015) recorded a specimen with lordosis and scoliosis in the posterior spinal column, and made suggestions for causes. Morovvati *et al*. (2015) outlined the histology and histomorphometry of the intestine, characteristic of an omnivore. Morovvati *et al*. (2018) described the histology and histomorphometry of the intestinal bulb, and this was generally similar to other cyprinoids. Soleimanian *et al*. (2021) described body shape changes for 50 days post-hatching.

Iranian specimens have the following meristic data:- dorsal fin branched rays 7(1), 8(27) or 9(1), anal fin branched rays 5(30), pectoral fin branched rays 15(2), 16(17), 17(10) or 18(1), and pelvic fin branched rays 7(1) or 8(29). Lateral line scales 32(4), 33(4), 34(4), 35(3), 36(8), 37(4) or 38(1). Total gill rakers 16(4), 17(3), 18(8), 19(7), 20(5) or 21(2), with some evidence of higher counts in larger fish. Pharyngeal teeth usually 2,3,5-5,3,2(19) with variants 2,3,5-4,3,2(2), 2,3,4-5,3,2(2), 2,2,5-5,3,2(1) and 1,2,5-4,3,2(1), in contrast to literature reports of 4 main row teeth being typical. Total vertebrae 46(1), 47(13), 48(9), 49(5) or 50(1) in fish seen by me, other counts presumably lacking four Weberian vertebrae.

**Sexual dimorphism.** Ali *et al*. (1981) found no sexual dimorphism in their Iraqi samples.

**Colour.** Overall colour has a pale rose to light orange effect, usually without other markings, but can be light grey to bronze. The back is a dark olive-brown to blackish-green with the flanks pale rose, light orange to yellowish to silvery, and belly silvery to milk-white. There may be an indistinct stripe along the mid-flank. Large fish have the upper flank darkened from the overall orange colour of the mid-flank and the lower flank scales are rimmed in white so they stand out. Lips are pale red. The operculum is golden. The pectoral, pelvic, anal and caudal fins are bright orange or pink at the base (perhaps white after preservation), distally blackish. Pectoral and pelvic fins may be dark overall with a reddish to reddish-brown tinge, and the leading edge of the pelvic fin pink. The anal fin may be a bluish-black distally. In some fish the caudal fin is black proximally and reddish distally. In large fish, the pectoral, pelvic, anal and caudal are progressively darker in this order. The anal and pelvic fins, the pectoral fins less so, may be heavily pigmented with melanophores on rays and membranes so as to

appear black in preserved fish. The dorsal fin is hyaline. The eye rim is yellow-green to lime-green. Young fish may have some scales darkened on their posterior half, giving a mottled effect and are silverier on the flank than large fish. Their pectoral and pelvic fins are more orange and the anal and caudal fins are only slightly tinged with colour. The caudal fin carries a lot of grey. The smallest fish have a very faint fin colouration. The peritoneum is black in adults, with scattered melanophores in young.

**Size.** Attains 96.0 cm and 9.7 kg in Dukan Dam, Iraq, and 96.0 cm and 11.0 kg in Atatürk Dam on the Euphrates River in Turkey (Al-Hakim *et al*., 1981; Oymak *et al*., 2008). Gruvel (1931) cited 1.5 m and 30.0 kg for Syria. Banister (1980) gave nearly 2.0 m and 100.0 kg but this may be confusion with *L. esocinus* although Krupp (1992) also cites almost 2.0 m. Reputedly reaches 60.0 kg in Lorestan (S. Nazeeri, pers. comm., 2000) and Ghofleh Marammazi (2000) found fish up to 20.0 kg in Khuzestan. Specimens reach 3.0 kg even in the small canals of the sugar-cane fields of Khuzestan.

**Distribution.** This species is found in the Tigris-Euphrates and the Orontes River basins and in southern Iran. In Iran, it is found in the Hormuz, Persis and Tigris River basins. In the Hormuz basin in the Galehgah, Hasan Langi, Kul and Shur rivers; in the Persis basin in the Ahram, Baghan, Dalaki, Dasht-e Palang, Dozgah, Gahar, Helleh, Kheyrabad, Mond, Qarah Aqaj, Shapur, Shur and Zohreh rivers, and Lake Parishan, although rare in the latter; and in the Tigris River basin in the Ab-e Shur, A'la, Alvand, Armand, Arvand, Baba Ahmad, Bahmanshir, Bala, Changuleh, Dez, Dinvar, Diyala, Ejerob, Gamasiab, Gangir, Godarkhosh, Hofel, Jarrahi, Kahnak, Kangir, Karkheh, Karun, Khorramabad, Marun, Nahr-e Shavor, Qareh Su, Qasr-e Shirin, Qopal, Ramhormoz, Razavar (= Raz Avar), Sezar, Shate-e Neisan, Shib, Shur, Simareh, Tangab, Tang-e Shiv and Zard rivers, the Dez and Karkheh dams, the Hawr al Azim, and Musa Estuary (Berg, 1949; Gh. Izadpanahi, pers. comm., 1995; Marammazi, 1995; M. Rabbaniha, pers. comm., 1995; Maafi, 1996b; Abdoli, 2000; H. R. Alizadeh, pers. comm., 2000; Eskandari *et al*., 2007; Bagheri *et al*., 2010, 2018; Raissy *et al*., 2010; Teimori *et al*., 2010; Biokani *et al*., 2011; Golchin Manshadi *et al*., 2012; Zareian *et al*., 2012; Bibak *et al*., 2013a; Biukani *et al*., 2013; Pazira *et al*., 2013; Pirani *et al*., 2013; Banaee and Naderi, 2014; Borkenhagen, 2014; Dadashi *et al*., 2014; Golchin Manshadi *et al*., 2014; Khoshnood, 2014; Khoramian *et al*., 2014a; Marammazi *et al*., 2014; Pazira *et al*., 2014, 2016; Raeisi Sarasiab *et al*., 2014; Ramin *et al*., 2014; Reyahi-Khoram *et al*., 2014; Abdolhahi, 2015; Esmaeili *et al*., 2015; Taghavi Niya and Velayatzadeh, 2015; Zamaniannejad *et al*., 2015; Keivany and Zamani-Faradonbe, 2016; Momtazan *et al*., 2016; Fatemi *et al*., 2019; Khamees *et al*., 2019; Jouladeh-Roudbar *et al*., 2020; photographs by A. Mahjoorazad).

Bushehr, Ahram or Bahoosh River (CC BY-SA 3.0, Milad Gerami).

**Zoogeography.** Karaman (1971) considered this species to have an Indian line of descent, placing it in the genus *Tor* that most subsequent authors restrict to the Indian subcontinent and Southeast Asia. See also under the genus above and under *Mesopotamichthys*.

**Habitat.** This species is found in rivers, streams, canals, jubes (= irrigation channels), dams, marshes, springs, and brackish environments. Marammazi (1994) considered this species to be versatile in its habitats in the Zohreh River which drains to the northern Persian Gulf (Persis basin). It was found throughout the river in contrast to *Mesopotamichthys sharpeyi* that, being stenohaline, was restricted in its distribution. The form with a well-developed median lobe occurs in rocky habitats. This species is the dominant fish in the Karun and Zohreh rivers (*Annual Report, 1994-1995, Iranian Fisheries Research and Training Organization, Tehran*, p. 48, 1996; *Iranian Fisheries Research and Training Organization Newsletter*, 17:1, 1997). Ghofleh Marammazi (2000) found it in almost all water bodies in Khuzestan where it occurred under a wide range of temperatures and salinities. However, its presence on the Khuzestan plain was for feeding while for reproduction it required more northerly areas with sandy or gravel substrates, high water flow, low temperatures and high oxygen content. Ramin (2009b) recorded this species as the most abundant in the Karkheh River out of 37 species and subspecies. Banaee and Naderi (2014) noted that it preferred slow-flowing water at 22ºC and shallow water with gravel beds for spawning in the Marun River. Interestingly, this species was not caught at one locality in the Marun River near Behbahan where gravel was being extracted (see photograph below). Cyprinids present were *Capoeta* sp., *Carasobarbus luteus*, *Carassius auratus*, *Cyprinion macrostomus*, *Cyprinus carpio* and *Garra rufa*, along with the leuciscids *Acanthobrama marmid*, *Alburnoides idignenesis* and *Alburnus sellal*. Heydarpour (1978) gave a temperature range of 9-31ºC for *A. grypus* under culture conditions in Khuzestan.

Khuzestan, Marun River near Behbahan showing gravel extraction,
CMNFI 2008-0163, 21 November 2000, Brian W. Coad.

van den Eelaart (1954) and Al-Hamed (1966b, 1972) described the habitat for this species in the Iraqi Tigris River as distributed throughout the river and its tributaries. It is a strong swimmer. Al-Rudainy (2008) stated that it could be found in the mid-water column in high current. Mature fish moved upstream to the spawning grounds and spent fish descended to their original habitat. In summer under low water level conditions and high temperatures, the smaller fish remained in the lower reaches of rivers but the larger fish migrated up rivers and tributaries, returning in September and October when temperatures fell. This species may enter marshes on floods, favouring areas where there is fresh river water, but returned to rivers as it required a higher oxygen concentration than most marsh residents. Water temperature ranged from 10.2ºC in March to 32.8ºC in August at Al-Diwaniya River, Iraq (Al-Jubouri and Mohamed (2019).

Habitat of *Arabibarbus grypus* (and *Carasobarbus luteus*, *Carassius auratus*, *Cyprinion kais* and *Luciobarbus esocinus*), CMNFI 2008-0168, Khuzestan, Dez River at Harmaleh, 27 November 2000, Brian W. Coad.

**Age and growth.** Dorostghoal *et al*. (2009) found mean body lengths were 36.5-43.5 cm and mean body weights were 835-1,012 g for their 120 fish from the Karun River. Hashemi *et al*. (2010, 2010, 2011) and Hashemi and Mortazavi (2011) examined 2,077 fish from the southern Karun River and found a size range of 20-76 cm and 52-11,170 g, growth was isometric, and growth and mortality parameters were $L_\infty$ = 86.64, K = 0.27, $t_0$ = -0.46, M = 0.5, F = 1.22, Z = 1.78 and E = 0.71. Relative yield per recruitment (Y'/R) was 0.037, relative biomass per recruitment (B'/R) was 0.29, exploitation ratio maximum sustainable yield ($E_{max}$) was 0.44, precautionary average target ($F_{opt}$) was 0.25 year$^{-1}$, and limit ($F_{limit}$) was 0.331 year-$^{1}$. The stock was overfished and fishing regulations were required. Khoramian *et al*. (2013a) examined 94 fish from the Ejerob Stream at Dezful and found a total length-weight relationship of LogW = -1.063 + 2.615LogL indicating negative allometric growth. The condition factor was 0.86. Maximum increase in length occurred in the first age group. von Bertalanffy growth parameters were $L_\infty$ = 1379.6, K = 0.085 and $t_0$ = -0.35. Khoramian *et al*. (2014a) found 193 fish from the Karkheh Dam had a total length and weight relationship of LogW = -2.49 + 3.319LogL for males, LogW = -2.96 + 3.46LogL for females and LogW = -2.68 + 3.31LogL for all fish, indicating positive allometric growth. The condition factor was 0.7 for males, 0.88 for females and 0.79 for all fish. Valikhani *et al*. (2020) combined fish from the Shadegan Wetland and the Dez and Karkheh rivers and reported a *b* value of 3.11 (isometric growth) and a condition factor of 8.19 (*sic*) for 4 fish (7.6-13.1 cm total length).

Bagheri *et al*. (2010) examined Dalaki River material comprising 72 fish, 6.8-26.4 cm

standard length, and found three age groups with $2^+$ years the most common. Growth was positively allometric in females (*b* = 3.27) and negatively allometric in males (*b* = 1.7, *sic*). Bibak *et al*. (2013a) gave a length-weight relationship for 57 fish, 6.6-37.8 cm total length, from the Dalaki River as $W = 0.02L^{2.93}$ indicating negative allometry. Pazira (2007) and Pazira *et al*. (2011, 2014) examined 2,494 fish from the Dalaki and Helleh rivers and found the oldest fish was 8 years old with most fish 2-3 years of age and 200-300 mm. $L_\infty$ was 1,120 for males and 1,165 for females. Condition factor varied with sampling station and was better in females. Life span in the Marun River was 6 years with male maturity at 2-3 years and female at 3-4 years (Banaee and Naderi, 2014). Keivany and Zamani-Faradonbe (2016) gave a *b* value of 2.94 for 32 fish, 3.3-8.1 cm total length, from the Zohreh River. Bagheri *et al*. (2018) found fish in the Dalaki and Helleh rivers were $1^+$ to $3^+$ years old with 50% of fish $2^+$ years old.

Al-Hakim *et al*. (1976) studied some aspects of the biology of this species in Razzaza Lake, Iraq. Males were longer than females before maturation and shorter thereafter. Females reached 13 years and males 8 years of age and fish matured at 45-48 cm total length in their fifth year. Males matured earlier than females. Al-Hamed (1966a, 1966b, 1972) working with Tigris River populations in Iraq, found males to mature at about 45 cm and females at about 50 cm, with most fish mature in their fourth year and spawning at the beginning of their fifth year of life. Some fish matured in age group 3 and some as late as age group 5. Maximum age observed was 12 years. Males outnumbered females, being two thirds of the fish on the spawning grounds. Al-Hakim *et al*. (1981) studied this species in the Dukan Dam, west of Sulaimaniyah, Iraq. Life span was 17 years for females and 11 years for males. Growth slowed with age, and especially after maturity, and was fastest in the first year of life. 30% of males matured at age group 3 (39 cm) and all were mature at age group 6 (48 cm). Ali *et al*. (1981) found this species to mature at 3-5 years of age and 40-50 cm in the Al-Therthar Dam (about 65 km northwest of Baghdad) and the Tigris River (Kut Dam) in Iraq. Jiad *et al*. (1984) studied this species in the Al-Hindiya Dam in Iraq and found similar results to the studies cited above.

Growth in a polluted section of the Diyala River, Iraq was poor compared to other populations (Khalaf *et al*., 1984, 1985).

Al-Jubouri (2019) examined 490 fish, total length 18.4-51.4 cm, from the Al-Diwaniyah River, Iraq and found this species comprised 5.97% of the fish assemblage, $W = 0.0127L^{2.8828}$ allometric growth, the sex ratio differed significantly from 1:1 in favour of females, mean values of relative condition factor for small fish, males and females were 0.82, 0.97 and 0.99, respectively, six age groups were recognized with lengths 20.2, 23.0, 32.0, 39.0, 43.9 and 48.3 cm, length group 31 cm dominated, and von Bertalanffy growth constants were $L\infty = 58$ cm, $K = 0.391$ and $t_o = -0.096$. The growth performance index ($\Phi$) was 3.13. The total (Z), natural (M) and fishing (F) mortality rates were assessed by applying the length cohort analysis and were 1.984, 0.385 and 1.599, respectively. The exploitation rate (E) estimate was 0.805, exceeding the optimal level of exploitation (E = 0.5), so this fish stock was overexploited. The following report was presumably based, at least in part, on this thesis. Al-Jubouri and Mohamed (2019) examined 853 fish from the Al-Diwaniya River, Iraq. This species constituted about 6.27% of the total fish catch. The length-weight relationship was $W = 0.021L^{2.7548}$, allometric growth. The mean relative condition factor was 0.91. Five age groups were recorded and their mean total lengths were 20.2, 32.0, 39.0, 43.9 and 48.4 cm, respectively. The growth model of the species was $L_t = 58\ [1\text{-}e^{-0.39\ (t-0.313)}]$. The growth performance index ($\Phi$) was 3.11. The overall female:male sex ratio was 1.47:1.

Oymak *et al*. (2008) examined age and growth in the Atatürk Dam on the Euphrates

River in Turkey. Fourteen age classes were found with age classes 4-6 for females and 2-4 for males dominant. von Bertalanffy growth equations were given for males and females.

**Food.** Iranian specimens contained filamentous algae, plant fragments and associated invertebrates. Pazira *et al*. (2009) noted that diet became more carnivorous with age (relative gut length shortens with age). They found that Plecoptera and Odonata were the food preference in the Dalaki and Helleh rivers although the highest frequency percentage of food items was Ephemeroptera in the Dalaki River. Ghofleh Marammazi (2000) considered it to be an omnivore and Bagheri *et al*. (2010) found Dalaki River fish were omnivores, becoming carnivores with increased age. Morovvati *et al*. (2015) stated that this fish is an omnivore as evidenced by the histology and histomorphometry of the intestine.

Al-Hamed (1965) found this species to be an herbivore in Iraq taking filamentous algae and higher plant parts. Incidental food items taken while feeding on plants included fish tissue and scales. Fallen ripe fruits from trees overhanging the water were also consumed as were cereal grains from loading docks. It may also take some small fishes. Al-Jubouri (2019) and Al-Jubouri and Mohamed (2019) found fish from the Al-Diwaniya River, Iraq were omnivores, feeding mainly on aquatic plants (33.8%), algae (26.7%), insects (25.5%), detritus (12.8%) and snails (1.0%). There was feeding overlap with *Carasobarbus luteus* (0.9).

**Reproduction.** Its presence in areas of the Khuzestan plain was mainly for feeding while reproduction occurred in the northern parts of this province where there are sandy and gravel substrates, fast current, low temperatures and high oxygen content (Ghofleh Marammazi, 2000). A prolonged spawning season in fish from the Karun River, late April to early August with the highest gonadosomatic index June-July, was determined by Dorostghoal *et al*. (2009) using macroscopic and microscopic techniques. They also noted that the fish migrate upstream for spawning in May. Embryonic and pre-larval development were examined by Akbarnezhad *et al*. (2010) who also noted average egg diameter was 2.18 mm and the fertilised egg was 2.44 mm on average. Females were mature at age $3^+$ years in the Dalaki River (Bagheri *et al*., 2010). Banaee and Naderi (2014) examined reproductive biology in the Marun River and found a male:female ratio of 2.35:1, maximum gonadosomatic index was in three- to five-year-old fish in March and April, and reproduction was from the end of March to the middle of July. Pazira (2007) and Pazira *et al*. (2014) examined fish from the Dalaki and Helleh rivers, and found reproduction to be asynchronous, occurring in May to July, the smallest gravid female was 2 years of age, fecundity range was 950-57,400 eggs and was correlated with length and age, egg diameter increased with age from 2 to 5 years but then tended to decrease from 5 to 6 years, egg diameter range was 0.837-1.943 mm, salinity negatively affected fecundity, and water temperature, when statistically significant, had a positive effect on fecundity, egg size and reproductive effort (defined as ratio of total egg mass to body mass).

van den Eelaart (1954) and Al-Hamed (1966b, 1972) studied the reproduction of this species in Iraq. Eggs were deposited on fine gravels overlying a layer of coarse sand in shallow, wide holes. Water depth varied from 30 to 150 cm. Egg diameter was 1.5 mm and fecundity up to 147,000 eggs. The spawning season on the Tigris River between Beled and Tigrit was late May to late June after an upriver migration in April. Fish appeared on the spawning grounds in schools just before dark and remained there until shortly before midnight, making loud noises by splashing, jumping and chasing. After spawning, the fish returned downriver but did not enter marshes, as these were now too warm. Al-Jubouri (2019) and Al-Jubouri and Mohamed (2019) found the highest values of the gonadosomatic index were 4.2

for females and 1.87 (or 1.78 by the second reference) for males in April at Al-Diwaniya River, Iraq. The fecundity of the species there ranged from 75,600 to 124,200 eggs. In Dukan Dam, Iraq spawning took place from the beginning of May until the end of June (Al-Hakim *et al*., 1981).

Oymak *et al*. (2008) examined reproduction in the Atatürk Dam on the Euphrates River in Turkey and found a female:male sex ratio of 1:1.34, with a spawning period in May to July, a fecundity up to 235,764 eggs, and a mean egg diameter of 2.183 mm.

**Parasites and predators**. Bykhovski (1949) reported a new species of monogenetic trematode, *Dactylogyrus pavlovskyi*, from this species in the Karkheh River, Iran. Ebrahimzadeh and Nabawi (1975) listed a nematode species *Philometra* and Ascaridae from this species in the Karun River. Ebrahimzadeh and Kailani (1976) recorded parasites in the genera *Myxosoma* (protozoan), *Isoglaridacris* (cestode) and also a nematode from fish taken in the Karun River. Moghainemi and Abbasi (1992) recorded a wide range of parasites from this species in the Hawr al Azim in Khuzestan. Molnár and Jalali (1992) described a new species of monogenean, *Dogielius persicus*, from fish in the Dez and Karun rivers of Khuzestan. Masoumian *et al*. (1994) described two new species of Myxosporea from the gills of this species in the Karun River, Khuzestan, namely *Myxobolus karuni* and *Myxobolus persicus*. Masoumian and Pazooki (1999b) listed *Myxobolus persicus, M. karuni, M. mesopotamiae* and *M. iranicus* from this species in various localities in Khuzestan. Molnár *et al*. (1996) described additional new species from this fish in Khuzestan, *Myxobolus iranicus* in the spleen and *Myxobolus mesopotamiae* in connective tissue of the caudal and pectoral fins. The latter myxosporean was also reported from *Barbus rajanorum* (*sic*) as was a new species *Myxobolus shadgani* infecting the gills - the identity of the host fish was unknown as *Barbus rajanorum* is not a distinct species. Myxosporeans are potentially dangerous to fishes such as *Arabibarbus grypus*, which may be used in fish culture in Khuzestan.

The monogeneans *Dactylogyrus pavlovskyi*, *D. barbioides*, *Dogielius persicus*, *Gyrodactylus sprostonae* and *Paradiplozoon* sp. were recorded from this species in the Karun River with heavier infestations in spring and summer than in autumn and winter. These gill parasites caused no serious injuries but were thought to be important in respect of monitoring infestation levels on fish farms in Khuzestan (www.avz1.8m.com/fulltext.htm, downloaded 28 October 2002).

Peyghan *et al*. (2001) reported *Neoechinorhynchus* sp. in fish from Khorramabad rivers. Peyghan *et al*. (2001) recorded *Myxobolus karuni* in 86.7% of fish in the Karun River at Ahvaz and Papahn *et al*. (2004) recorded the monogeneans *Dactylogyrus barbioides*, *D. pavlovskyi*, *Dogielius persicus*, *Gyrodactylus sprostonae* and *Paradiplozoon* sp. from the same locality, the latter two being first records for the host in Iran. Farahnak *et al*. (2002) recorded *Contracaecum* sp. and *Anisakis* sp. from this fish in Khuzestan Province. Mortezaei *et al*. (2007) found the nematode *Rhabdocona denudata* in fish from Shadegan Marsh, Khuzestan. Barzegar *et al*. (2008) recorded the digenean eye parasite *Tylodelphys clavata* from this fish. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Argulus* sp. and *Ergasilus* sp. on this species. Mesbah *et al*. (2010) examined fish from the Karkheh River and found the zoonotic nematodes *Anisakis* sp., *Capillaria* sp. and *Contracaecum* sp. Raissy *et al*. (2010) found ichthyophthiriasis (infection with *Ichthyophthirius multifilis* - ich or white spot disease), which causes epizootics in wild and cultured fishes, in fish from the Armand River in Chahar Mahall and Bakhtiari Province. Golchin Manshadi *et al*. (2012) and Golchin Manshadi (2017, 2018) recorded *Myxobolus bramae*, *M. karuni*, *M. persicus*, *Dactylogyrus barboides*

and *D. pavlovskyi* from this species in Lake Parishan. Raissy and Ansari (2012) also examined fish from the Armand River and found *Ichthyophthirius multifilis* (Ciliophora), *Dactylogyrus lenkorani* (Monogenea) and *Rhabdocona denudata* (Nematoda). Mohammadi *et al*. (2019) reported *Diplostomum spathaceum* from the eyes and Bothriocephalidae, *Anisakis, Contracaecum*, *Khawia*, *Neoechinorhynchus* and *Varelacreptotrema* from the gastro-intestinal tract of fish from Shadegan Wetland. Moumeni *et al*. (2020) recorded the zoonotics *Anisakis* spp., *Contracaecum* spp., *Philometra karunensis*, *Philometra* spp. and *Capillaria* spp. from this fish in Iran.

This species is eaten by *Silurus triostegus* (Mesopotamian catfish) (ZSM 25717, "from the stomach of a wels").

**Economic importance.** This species is the preferred catch of anglers at Ahvaz in Khuzestan, with bread or potato as bait. There is a good demand for it in local markets of Khuzestan (Ghofleh Marammazi, 2000). Peyghan *et al*. (2001) reported that it is an economically important species with a good market value in the Khorramabad region. Poria *et al*. (2013) noted that it is important as a commercial and sport fish in the Gamasiab River in Kermanshah Province. Salemi and Sayahi (2018) recorded this species on the market at Mahshahr, Khuzestan.

An important food fish, with desirable taste according to Al-Rudainy (2008), comprising 23% of the total fish production in Iraq, for example, and forming the most important commercial fish there (Al-Hakim *et al*., 1981). Petr (1987) reported the catch for all Iraq in 1976 as 519 t. The weight at the Basrah fish market from October 1975 to June 1977 was only 3,330 kg however (Sharma, 1980) and Khalaf *et al*. (1984) ranked it third in the inland wholesale trade of Iraq for the period 1967-1970. The price of this fish in Iraq was U.S. $6 per kilogramme pre-war and was U.S. $13.50 in 2006 (Sabah, 2006). Parmaksız and Şeker (2018) stated that this fish was preferred by local people in Turkey for its delicious flesh.

The bacteria *Lactobacillus plantarum* and *L. bulgaricus* isolated from the intestine of this fish and added to the diet of common carp, caused an increase of beneficial microflora and improved growth performance (Hosseini *et al*., 2016).

This species is supposed to be the one mentioned in the Jewish Talmud as a kosher fish tasting like pork. According to rabbinic writings, seven hundred pure (permitted) fish were exiled with Israel to Babylonia, and all returned except for the "shibuta" (www.jpost.com., downloaded 19 September 2005; Zivotofsky and Amar, 2006; Moradi, 2017).

**Experimental studies.** Dadelahi Sohrab *et al*. (2009) found lead and cadmium levels in fish from the Arvand River were higher than acceptable by international standards. Alishahi (2010) and Alishahi and Mesbah (2010) found that commercial nanosilvers, which have antimicrobial properties, were severely toxic to this species and cannot be used in waters inhabited by this fish ($LC_{50}$ 96 h being 0.076-0.127 μg/l). Askari Sari (2010) found higher concentrations of heavy metals (cadmium, lead and mercury) in fish from the Karun River in comparison to the Karkheh River, higher concentrations in gill and liver tissues than muscle, higher lead than other heavy metals, and this species was more contaminated than *Liza* (= *Planiliza*) *abu* (abu mullet). Askary Sary and Mohammadi (2011a) examined fish from the downstream Dez and Karun rivers and found they were highly contaminated with such heavy metals as cadmium, lead, nickel and mercury, varying between tissues and the two rivers, but exceeding acceptable levels. Khoshnood and Khoshnood (2011) sampled fish from two stations in the Karun River, Khuzestan and found relatively high total mercury levels in muscle tissue at 8.47 and 0.08 μg/g. Ghorbani Ranjbary *et al*. (2013) found fish from the Karun River

had higher lead than mercury and cadmium concentrations and concentrations were higher in gills and higher than in the mullet *Liza* (= *Planiliza*) *abu* (abu mullet). Abdi and Alishahi (2014) showed that the pesticide diazinon was toxic to this species and toxicity increased with pesticide concentration. Tabandeh *et al*. (2014) and Mohammadiyan *et al*. (2019) examined tissue distribution and activity of rhodanese, a mitochondrial enzyme that detoxifies cyanide, in fish from the Karun River. This data could then be used to assess severity of cyanide contamination of water or fishes. Tabandeh *et al*. (2014) found mercaptopyruvate sulphur transferase, a cyanide-detoxifying enzyme, in tissues of this species. Khabazian Zadeh *et al*. (2015) studied accumulation of the herbicide atrazine (used in the sugar cane fields of Khuzestan) in fillets. Hoseini *et al*. (2015) determined that trichlorophon (trichlorfon) was the best organophosphorous pesticide based on its effects on *A*. *grypus* but the high toxicity of malathion and chlorpyrifos indicated they should not be used not only in aquaculture, but also in agriculture. The authors proposed the use of other pesticides such as diazinon in agriculture as an alternative. Khabazian Zadeh *et al*. (2016) found that chronic atrazine toxicity adversely affected haematological parameters and the $LC_{50}$ 96 h was 65 mg/l. Momtazan *et al*. (2016) found mercury levels of 0.809 mg/kg in muscle of fish from the Marun River at Behbahan, acceptable according to the Environmental Protection Agency standard but higher than the World Health Organization limit. Alishahi *et al*. (2018) found that penicillamine and EDTA (ethylenediaminetetraacetic acid, a chelating agent) had a therapeutic effect and reduced the toxicity of heavy metals and silver nanoparticles, the former being more effective in this fish. Salemi and Sayahi (2018) showed that the average concentration of cadmium, nickel, lead, chromium and zinc in fish bought at market in Mahshahr, Khuzestan was 2.848, 1.933, 23.3, 23.93 and 0.045 mg.dry weight, with the amount of cadmium, lead and nickel higher than the standards set by world organisations so consumption of fish from this area would have a severe risk for consumers. Velayatzadeh and Askary Sary (2020) found the health risk of mercury in consumption of this species in southwest Iran was over 1 for both adults and children and so it is advisable to pay more attention to the consumption of this fish.

Marammazi and Kahkesh (2011) studied nine experimental diets for juveniles of this species as part of a polyculture system. The best growth and feed utilisation were shown by a diet comprising 250-300 g $kg^{-1}$ crude protein and 10.46 MJ $kg^{-1}$ (metabolisable energy level). Chelehmal Dezfoolnezhad *et al*. (2014) characterised the effect of dietary vitamin C on the immune system and found a significant increase in the white blood cell count. Mohammadian *et al*. (2015) studied the effects of the commercial prebiotic immunogen, added to the diet, on the intestinal microflora and carcass composition of Iranian fingerlings, finding positive effects on both. Safari *et al*. (2015, 2016) fed *Aloe vera* extract for 60 days and found improved growth and blood parameters at levels of 0.2 and 0.5%. Mohammadian *et al*. (2016) found juvenile fish fed with a diet containing the probiotics *Lactobacillus plantarum* and *L*. *delbrueckii* ssp. *bulgaricus* had significantly higher survival rates than control diets after challenge with the bacterium *Aeromonas hydrophila*. The probiotics occurred naturally in the gut of this fish species. Mohammadian *et al*. (2017) detailed differences in blood biochemical parameters of fish fed prebiotic and those not so fed. Mohammadian *et al*. (2017) found that supplementation of bacteria isolated from the intestine of this fish, particularly *Lactobacillus delbrueckii* subsp. *bulgaricus*, improved growth performance, intestinal microbiota and some digestive enzyme activities in juveniles. It could therefore be isolated and used as a growth enhancer like commercial probiotics. Mohammadian *et al*. (2017) showed that 5 x $10^7$ CFU $g^{-1}$ (colony-forming unit or number of viable cells) of *Lactobacillus casei* for 30 days and 5 x $10^8$

CFU g$^{-1}$ for 60 days were the best probiotic doses for juveniles. Namvazadeh *et al*. (2017) found fish from the Karun River at Shushtar, Khuzestan had mercury levels higher than farmed *Cyprinus carpio* fed a healthy artificial diet as the former were exposed to biomagnification in a natural setting. The level was still acceptable for human consumption. Javaheri Baboli and Anvari (2018) studied the optimum weaning time for larvae fed rotifers and a formulated diet, the results suggesting 18 days of live food was essential to obtain larvae with high growth and survival. Safari *et al*. (2019) determined that addition of *Aloe vera* to food at various concentrations enhanced growth rate and haematological parameters. Mohammadian *et al*. (2020) found that feeding probiotic *Lactobacillus casei* could enhance the immune responses and gene expression. Mohammadian *et al*. (2021) showed that dietary supplementation with immunogen, particularly at the level of 1.5%, positively altered growth parameters, carcass protein, intestinal microflora and immune responses.

Javaheri Baboli and Fazeli Rad (2016) investigated the composition of fatty acids in fed and starved larvae, the latter showing a decrease in mono- and polyunsaturated fatty acids while saturated fatty acids increased and, in the former, polyunsaturated and saturated fatty acids decreased while monounsaturated fatty acids increased significantly. Sharifi *et al*. (2019) found differences in levels of several lipids in cultured fish, by sex in both blood and muscles.

Petr (1987) suggested that this species be investigated for fish farming in Khuzestan. The Khuzestan Fisheries Research Centre at Ahvaz experimented with this species in pond culture (Emadi, 1993a; *Annual Report, 1994-1995, Iranian Fisheries Research and Training Organization, Tehran*, p. 6, 1996). Moosavi *et al*. (2015) briefly mentioned artificial breeding in Khuzestan and the similarities and differences between this species and *Mesopotamichthys sharpeyi*. Basak Kahkesh *et al*. (2010) and Bosak (*sic*) Kahkesh *et al*. (2012) found that female broodstock 4,518±780 g, 4±1 year and 79.12±4.36 cm had the maximum working fecundity (13,000.37±4,652.57 eggs) in artificial propagation. The study found no significant difference between sexes in blood parameters. Basak Kahkesh *et al*. (2011) looked at the effect of size of female broodstocks on functional fecundity, fertilisation rate, hatch rate and larval survival rate, finding these indices increased until a weight of 4,518 g and beyond that decreased.

Kahkesh *et al*. (2011) compared the effectiveness of several hormones on maturation, recommending a specific combination (LHRH-a2+CPE). Ghanemi and Khodadadi (2017) found a dose of 1 ml/kg.bw of ovaprim and 3 mg/kg.bw of pituitary extract had positive effects on such reproductive parameters as spawning rate, egg weight/g.bw and working fecundity. Charkhab *et al*. (2018) determined timing of gonadal differentiation and observed sexual maturation at 300 days in males and 217 days in females, necessary details for artifcial proliferation. Mabudi *et al*. (2019) found a three-stage injection of carp pituitary extract (4 mg/kg) and the hormone LHRHa2 (7 µg/kg) was the best for artificial reproduction of broodstock from Khuzestan waters in terms of egg weight, relative fecundity, fertilisation, hatching rate, larvae number and percent of larvae alive.

Khodadadi *et al*. (2016) gave details of sperm density and motility, composition of seminal plasma, spermatocrit, and sperm dimensions. Khadjeh *et al*. (2010) studied the haematology of this species as this provided useful criteria for assessing health status in intensive rearing. Abbasi Dobandar *et al*. (2017) found that the anaesthetics MS-222 and 2-phenoxyethanol caused stress on fish blood factors (glucose and cortisol). Abbasi Dobandar *et al*. (2019) determined the effective anaesthetic doses of MS-222 and 2-phenoxy ethanol were 300 µl/l and 50 mg/l, respectively. 2-phenoxy ethanol caused a higher rise in stress indicators. Alishahi *et al*. (2019) showed that the lethal effects of ketamine anaesthetic decreased

significantly when used along with 15 mg/l of the sedative acepromazine. Javadzadeh *et al*. (2019) investigated the effect of 2-phenoxy ethanol on the liver and found vacuolisation, enlargement of fat cells and dilatation of hepatic sinusoids. These effects were less at doses of 400 and 600 mg/l.

**Conservation.** The stock of this species in the Gamasiab River of the Tigris River basin was severely reduced and only three fish were caught in western Iran in the Zagros rivers during a four-year survey (J. Valiallahi, www.modares.ac.ir, downloaded 4 July 2000; pers. comm., 2001). Dorostghoal *et al*. (2009) noted that this species was caught on the spawning migration and while spawning and this accounted for its decline. This species was considered to be on the verge of extinction in the Gamasiab River, through pollution, overfishing, dam building, aquaculture, and introduction of exotics (www.iranmania.com, downloaded 29 December 2006). However, Izadi *et al*. (2013) fished the Gamasiab, Qarasu (= Qareh Su) and Razavar (= Raz Avar) rivers at 10 stations each for 12 months and found this species to be more abundant than *Luciobarbus esocinus* and *L*. *subquincunciatus*. Valiallahi (2017b) cited a study along the Lesser Zab River that was unable to detect any fish. In contrast, Pazira *et al*. (2009) found 2,494 fish in the Dalaki and Helleh rivers of the Persis basin in a sampling period of 14 months. This may relate to the different habitats of highland and lowland rivers, or other factors such as pollution and overfishing. It is reproduced artificially and stocked in Iran.

It is probably in decline in Turkey (Fricke *et al*., 2007). Parmaksız and Şeker (2018) stated that numbers in the Euphrates River of Turkey declined from overfishing. Smith *et al*. (2014) listed it as Vulnerable, overfishing being the principal threat. Listed as Vulnerable by the IUCN (2015) through overfishing, dams blocking migrations, water abstraction, and pollution, and as of Least Concern by Jouladeh-Roudbar *et al*. (2020) because it is widespread with numerous populations and no known major threats. Freyhof *et al*. (2020) considered it to be threatened mostly by overfishing plus excessive water abstraction, pollution, commercial factors, extended periods of drought and construction of dams. However, it can colonise and even thrive in reservoirs.

**Sources.** Type material:- *Barbus grypus* (NMW 54161) and *Labeobarbus kotschyi* (NMW 49729).

Iranian material:- CMNFI 1979-0155, 1, 42.8 mm standard length, Fars, spring at Gavanoo (28º47'N, 54º22'E); CMNFI 1979-0291, 1, 31.4 mm standard length, Kermanshah, river in Diyala River drainage (34º24'N, 45º37'E); CMNFI 1979-0356, 5, 22.5-40.7 mm standard length, Khuzestan, Karkheh River drainage stream at Hoveyzeh (31º27'N, 48º04'E); CMNFI 1979-0360, 1, 375.5 mm standard length, Khuzestan, canal branch of Karkheh River (31º40'N, 48º35'E); CMNFI 1979-0364, 1, 22.3 mm standard length, Khuzestan, river at Abdolkhan (31º52'30"N, 48º20'30"E); CMNFI 1979-0384, 2, 202.2-222.2 mm standard length, Khuzestan, river in Ab-e Shur drainage (32º00'N, 49º07'E); CMNFI 1979-0391, 1, 220.5 mm standard length, Khuzestan, stream in Marun River drainage (31º28'N, 49º51'E); CMNFI 1979-0392, 1, 62.4 mm standard length, Khuzestan, Zard River (ca. 31º32'N, ca. 49º48'E); CMNFI 1979-0395, 2, 32.7-38.0 mm standard length, Khuzestan, stream in Marun River drainage (ca. 30º57'N, ca. 49º51'E); CMNFI 1979-0402, 1, 80.7 mm standard length, Bushehr, Mond River 12 km north of Kaki (ca. 28º25'N, ca. 51º32'E); CMNFI 1991-0153, 1, 253.5 mm standard length, Khuzestan, Zohreh River (no other locality data); CMNFI 1993-0141, 1, 80.2 mm standard length, Bushehr, Dalaki River (29º28'N, 51º15'E); CMNFI 1995-0009A, 4, 51.2-78.8 mm standard length, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 2008-0120, not kept, Khuzestan, Rud Zard at Rud Zard (31º22'N, 49º43'E); CMNFI 2008-

0130, not kept, Khuzestan, stream at Kupal (31º15'N, 49º10'E); CMNFI 2008-0132, 2, 194.2-268.5 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); CMNFI 2008-0168, not kept, Khuzestan, Dez River at Harmaleh (31º57'08"N, 48º33'48"E); CMNFI 2008-0169, not kept, Khuzestan, irrigation ditch in sugar cane fields (31º58'42"N, 48º31'07"E); CMNFI 2008-0171, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'20"N, 49º52'44"E); CMNFI 2008-0260, 1, 136.8 mm standard length, Fars, Zohreh River (no other locality data); BM(NH) 1980.8.28:7, 1, 72.0 mm standard length, Khuzestan, Dezful (32º23'N, 48º24'E); ZMH 2508, 1, 343.3 mm standard length, Khuzestan, Karun River at Ahvaz (31º19'N, 48º42'E); ZSM 21862, 5 (one fish in CMNFI 1989-0084, 86.1 mm standard length), 60.5-86.9 mm standard length, Khuzestan, Dez River at Harmaleh (31º57'N, 48º34'E); ZSM 21864, 1, 157.7 mm standard length, Khuzestan, Dez River at Harmaleh (31º57'N, 48º34'E); ZSM 25716, 2, 76.4-79.3 mm standard length, Khuzestan, Dez River at Harmaleh (31º57'N, 48º34'E); ZSM 25717, 1, 78.5 mm standard length, Khuzestan, Dez River at Harmaleh (31º57'N, 48º34'E).

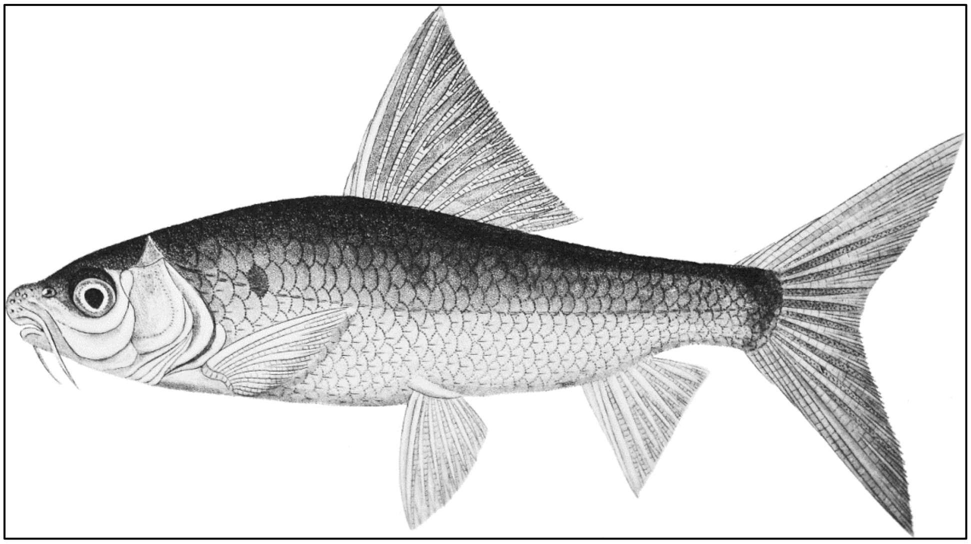
Comparative material:- BM(NH) 1874.4.28:24-26, 3, 231.2-254.7 mm standard length, Iraq, Tigris River at Baghdad (33º21'N, 44º25'E); BM(NH) 1920.3.3:1-18, 5, 104.8-196.0 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1973.5.21:191, 1, 205.4 mm standard length, Iraq, Shatt-al-Arab; BM(NH) 1973.5.21:192, 1, 139.5 mm standard length, Iraq, Shatt-al-Arab; BM(NH) 1974.2.22:1283-1284, 2, 121.0-164.5 mm standard length, Iraq, Khalis (33º49'N, 44º32'E); BM(NH) 1974.2.22:1299-1315, 9, 64.9-101.5 mm standard length, Iraq, branch of Khalis River (no other locality data); BM(NH) 1974.2.22:1317, 93.9 mm standard length, Iraq, branch of Khalis River (no other locality data); BM(NH) 1974.2.22:1323, 1, 160.1 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1974.2.22:1328, 1, 161.9 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); CMNFI 1993-0164, 1, 267.2 mm standard length, Iraq (no other locality data); KU 10516, 1, 124.1 mm standard length, Iraq, Basrah (30º30'N, 47º47'E).

## Genus *Bangana*
Hamilton, 1822

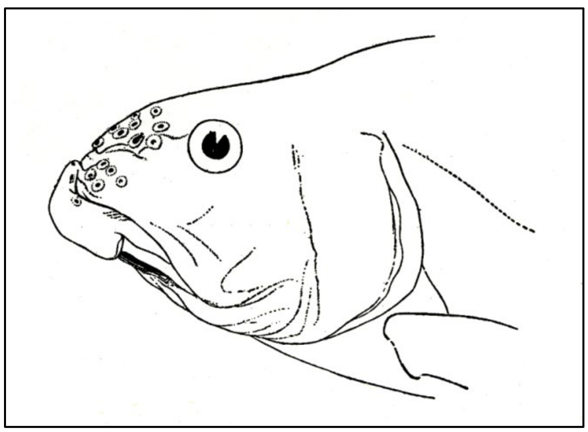
This genus has about 23 species in Southeast and South Asia with one reported from Iran. Members of this genus were formerly placed in *Labeo* Cuvier, 1816.

The genus is characterised by having an upper jaw fully enclosed by the lip and the median part of the upper lip covered by the rostrum. Other characters in combination also relate to jaw characters such as having a thick, smooth and pendulous rostral fold, separated from the upper lip by a deep groove and disconnected from the lower lip around the mouth corners, the lateral portions of the upper lip being smooth or slightly papillose and laterally connected with the lower lip, a lower lip anteriorly separated from lower jaw by a transverse groove extending along the length of the entire lower jaw, with a free anterior margin containing numerous papillae on the dorsal surface, a lower jaw heavily cornified with a sharp cutting edge, a postlabial groove uninterrupted and forming a deep transverse groove that fully separates the lower lip from the mental or chin margin, or broadly interrupted, or confined only to the side of the lower jaw, partially separating the lower lip from the mental region, and usually 10-12 dorsal fin rays (Zhang and Chen, 2006). The genus also lacks a dorsal fin unbranched thickened ray and the anterior and posterior barbels are about equal in size when both are present.

***Bangana dero***
(Hamilton, 1822)



*Bangana dero*, after Hamilton (1822).



*Bangana dero*, after Hora (1936).

*Bangana dero*, http://zzzy.cafs.ac.cn/, Sider_u0.jpg
(CC BY-NC 3.0).

**Common names.** None**.**

**[**Gid, kalabans and river rohu; khurero or torki in Pakistan].

**Systematics.** *Cyprinus dero* was described originally from the Brahmaputra River, India. No types are known. Zheng *et al*. (2019) revised the genus and reaffirmed the validity of this species.

**Key characters.** The characters of the genus identify this species, especially those of the mouth.

**Morphology.** The body is rounded and moderately deep, being deepest at the anterior dorsal fin level. The caudal peduncle is deep and compressed. The back in front of the dorsal fin is convex. Features of the head are definitive. The snout is prominent and overhangs the mouth. It lacks a lateral lobe but has a deep groove across it in front of the nostrils. The mouth is inferior, narrow and has thick and continuous lips. The lower lip is papillated internally. There is one pair of thin maxillary barbels. The eye is small and not visible from the underside of the head, and the rear of the eye is at the beginning of the anterior half of the head. The dorsal fin margin is slightly emarginate and the fin does not quite reach the anal fin level when appressed. The dorsal fin origin is anterior to the level of the pelvic fin origin. The anal fin margin is straight to emarginate and the fin does not reach back to the caudal fin base. The caudal fin is moderately forked with rounded to pointed tips. The pelvic fin margin is rounded and the fin does not extend back to the anus. The pectoral fin margin is rounded and the fin does not extend back to the pelvic fin origin.

Dorsal fin unbranched rays 2-3, dorsal fin branched rays 9-12, anal fin unbranched rays 2-3, anal fin branched rays 5, pectoral fin branched rays 14-17, pelvic fin branched rays 7-8, lateral line scales 38-44, and scales around caudal peduncle 22-26. There is a pelvic axillary scale. Scales have numerous fine circuli, an anterior focus, very few anterior radii, many posterior radii concentrated in mid-scale and running almost parallel to the dorsal and ventral scale margins, dorsal and ventral scale margins almost parallel, posterior margin rounded and anterior margin wavy or indented, and posterior field tuberculate. Total gill rakers number ca. 35 touching the second or third adjacent raker when appressed. Pharyngeal teeth are 2,4,5-5,4,2 with curved and flattened crowns. Chromosome number is 2n = 48-50 (Arai, 2011).

**Sexual dimorphism.** Large tubercles are often present on the snout in males, relatively

few in number.

**Colour.** The back is bluish- or brownish-black or olive-green, the flanks bluish-silvery, with scales often tinged red and outlined in red, and there is faint mid-flank stripe. The belly is yellowish-pink. There is a black spot on the flank behind the operculum above the fifth lateral line scale. Young fish have a black blotch at the caudal fin base. Fins are blackish with faint reddish tones, yellowish on the ventral fins. The margin of the dorsal fin is dusky. The caudal fin often has orange tips.

**Size.** Attains 60.0 cm total length (Shrestha, 2008).

**Distribution.** This species is found in Afghanistan, Pakistan, India, Nepal, Bangladesh, Myanmar and east to China. A single specimen has been caught in southeastern Iran in the Rotak River, Hamun-e Mashkid River basin, Baluchestan at 27°09'N, 62°16'E and 1,090 m altitude (Esmaeili *et al*., 2013a, 2013b).

Habitat of *Bangana dero* (and *Carassius auratus*), Baluchestan, Rotak River, after Esmaeili *et al*. (2015).

**Zoogeography.** The Iranian record is the westernmost one for the species.

**Habitat.** This species is found in rivers, streams and lakes generally. It can live in torrential hill streams and in the moderate currents of middle reaches but may migrate to the warmer waters of lakes and streams during the winter. There is also a spawning migration in spring to hill streams. In Pakistan, it preferred high altitudes, high levels of dissolved oxygen and gravelly river beds (Rafique, 2007). Young fish were found in schools but older fish tended to be solitary.

**Age and growth.** Half the males and females matured at about 25-30 cm in the first year of life in the northeast hill region of India (Biswas *et al*., 1984). Eight age classes were reported by Tandon *et al*. (1989) in Himachal Pradesh, India.

**Food.** Food items in Pakistan included diatoms, plants and detritus, and their associated

invertebrates such as beetle larvae (Butt and Khan, 1987). In Nepal, algal slime, crustaceans, fishes and frogs were eaten (Shrestha, 2008).

**Reproduction.** In the Garhwal Himalayas, this species spawned in March to June (Badola and Singh, 1984) and in May-June in Kashmir. Eggs were laid among stones near the stream bank at a depth of 30-35 cm in slow water. Water temperatures were 12.6-17.5°C and dissolved oxygen was 9.3-9.9 p.p.m. Fertilised eggs were greenish, and adhered to plants in Nepal (Shrestha, 2008). In the northeastern hill region of India, mature fish were found from late March to August with gravid oocytes in April-May and the gonadosomatic ratio peaking in May-June. Spawning occurred in June-July and fry and fingerlings (5-10 cm) were caught in September-October. Fecundity reaches 233,205 eggs, elsewhere 710,394 eggs.

**Parasites and predators.** Malekzehi *et al*. (2013, 2014) recorded *Lernaea* sp. from fish in the Mashkel River basin.

**Economic importance.** The flesh of this species is esteemed as food and it is caught both commercially and by anglers in other countries. It is also used as bait for such species as the mahseer, *Tor macrolepis*, in Pakistan and India.

**Experimental studies.** None.

**Conservation.** Listed as Least Concern by the IUCN (2015).

**Sources.** Iranian material:- None.

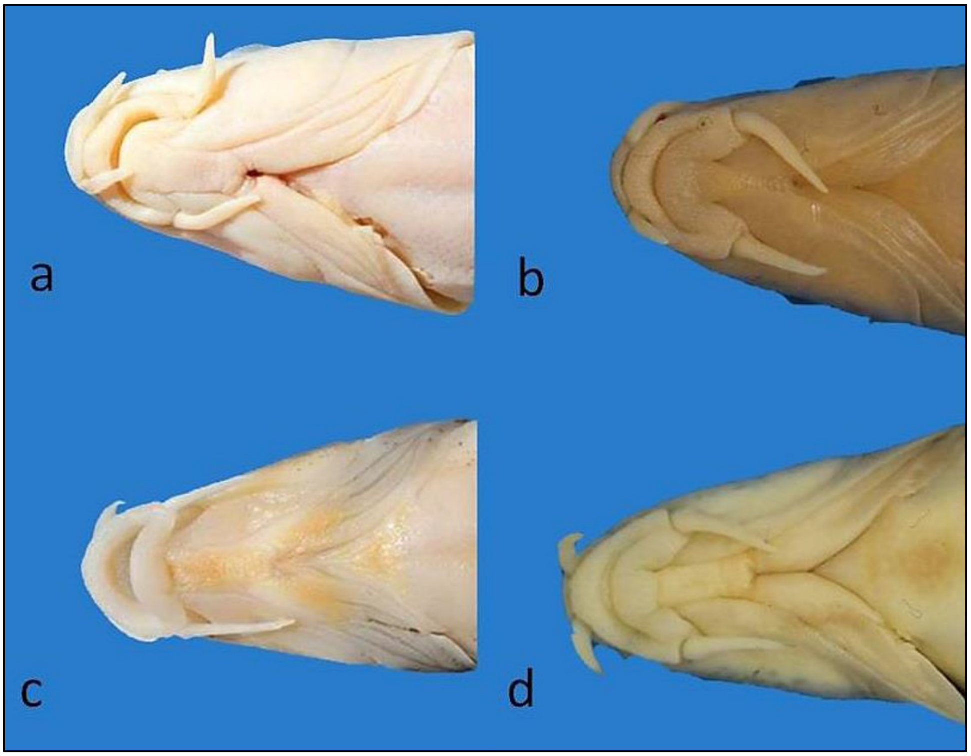
Comparative material:- SNM-PM 6842, 1, 182.5 mm standard length, Afghanistan, Kabul River near Daruntah (ca. 34°28'N, 70°22'E).

## Genus *Barbus*
Daudin, 1805

The barbels, genus *Barbus sensu lato*, were found in Europe, Southwest Asia and Africa and comprised about 800 nominal species with about 17 formerly recognised in Iran. Only five species in Iran are now assigned to this genus.

This genus once included a wide variety of species and was something of a catchall, serving to cover groups of species which had not been satisfactorily defined as distinct genera to general acceptance. Much of the literature on a variety of now recognised Iranian genera and species appeared under this name, hence the following review.

Characters in Southwest Asian species formerly included a rounded or compressed body of moderate to very large size, large to very small scales (lateral line scale count range at least 23-103), no scale sheath around the anal fin, scales had moderate to high numbers of radii and numerous fine circuli, the presence of barbels in most species, usually two pairs, often one pair and sometimes none (and individually variable within species), lips variably developed from thin to thick and fleshy, the lower lip sometimes with a well-developed median lobe (and lip development individually variable within species), the last unbranched ray in the short dorsal fin (usually 7-8 branched rays but sometimes more) thickened and spine-like and may bear teeth (denticles) or be smooth, a short anal fin, usually with 5 branched rays (but some with 6), pharyngeal teeth in three rows with hooked or spoon-shaped tips but sometimes heavy and massive or molariform, gut short, peritoneum white to brown or black, and colour usually brown without distinctive markings in the form of stripes, bands or spots (*Luciobarbus subquincunciatus* was an exception).




*Barbus* ventral heads, a = *B. cyri*, b = *B. lacerta*, c = *B. miliaris*, d = *B. karunensis*, Hamid Reza Esmaeili.

Bănărescu and Bogutskaya in Bănărescu and Bogutskaya (2003) restricted *Barbus* to tetraploid species with scales having divergent striae. These species have 7-8, occasionally 9, dorsal fin branched rays, 5 anal fin branched rays, papillose lips and two pairs of barbels. This then excludes species placed in *Carasobarbus*, *Kosswigobarbus* (= *Carasobarbus*), *Mesopotamichthys* and *Tor* (= *Arabibarbus* for the Middle East) (see below). Two groups of species can be distinguished in this restricted *Barbus* according to Bănărescu and Bogutskaya in Bănărescu and Bogutskaya (2003), namely those with 5 pharyngeal teeth in the main row and a papillose lower lip separated from the chin by a groove and those with 4 pharyngeal teeth in the main row and a lower lip without papillae and continuous with the chin, this latter group being formerly recognised as the genus *Luciobarbus* Heckel, 1843. The European/Caucasian members of *Barbus sensu stricto* in Iran was then *lacerta* (and *cyri*) and of *Luciobarbus* (treated as a subgenus in Bănărescu and Bogutskaya in Bănărescu and Bogutskaya (2003)) *brachycephalus* (= *caspius*) and *capito*.

Berrebi and Tsigenopoulos in Bănărescu and Bogutskaya (2003) and Tsigenopoulos *et al*. (2003) reviewed *Barbus* using molecular markers. They included *Barbus cyri* (a subspecies of *B. lacerta* according to some authors then) and *B. lacerta* in the subgenus *Barbus*, their Northern Mediterranean Group, and *B. brachycephalus* (= *caspius*), *capito*, *esocinus*, *longiceps*, *mursa*, *mystaceus*, *pectoralis*, *rajanorum*, *subquincunciatus*, *xanthopterus* and probably *barbulus*, *kersin*, *schejch* and *scincus* in the subgenus *Luciobarbus*, their Southern Group. These two subgenera, now genera, can be distinguished by tuberculation, being small and numerous on the head and anterior body in *Barbus* and few and large on the snout in *Luciobarbus*. Levin (2004) studied phenetic relationships of seven Caucasian taxa and concurred with the division into *Barbus* and *Luciobarbus*, with divergence between them

occurring in the Late Oligocene 23.23-31.86 MYA and confirmed by fossil evidence.

The genus *Barbus sensu lato* Daudin, 1805 has been split into a number of genera which are now finding general acceptance. Names used in the literature for Southwest Asia include *Tor* Gray, 1834 *sensu* Karaman, 1971, *Labeobarbus* Rüppell, 1835, *Systomus* McClelland, 1838, *Luciobarbus* Heckel, 1843, *Barynotus* Günther, 1868 (preoccupied), *Aspiobarbus* Berg, 1933, *Bertinius* Fang, 1943 (and *Bertinus* Banister, 1980, a misspelling), *Bertinichthys* Whitley, 1953 (an unneeded replacement of *Bertinius*), *Carasobarbus* Karaman, 1971, *Kosswigobarbus* Karaman, 1971 and *Mesopotamichthys* Karaman, 1971. *Barbus grypus* has been placed in the genus *Tor* but is now placed in the genus *Arabibarbus* Borkenhagen, 2014. Borkenhagen (2017a) confirmed the validity and relationship of *Arabibarbus*, *Carasobarbus* and *Mesopotamichthys* using mtDNA, although the relationships between them were not resolved. *Bertinius* was regarded as a synonym of *Luciobarbus* in Bănărescu and Bogutskaya in Bănărescu and Bogutskaya (2003). *Carasobarbus kosswigi* and *C. sublimus* were formerly placed in the genus *Kosswigobarbus*. A summary table of generic and/or subgeneric names is given below:-

| Species | Original genus | Genus |
|---|---|---|
| *barbulus* | *Barbus* | *Luciobarbus* |
| *capito* | *Cyprinus* | *Luciobarbus* |
| *caspius* | *Barbus* | *Luciobarbus* |
| *conocephalus* | *Barbus* | *Luciobarbus* |
| *cyri* | *Barbus* | *Barbus* |
| *esocinus* | *Luciobarbus* | *Luciobarbus* |
| *grypus* | *Barbus* | *Arabibarbus* |
| *karunensis* | *Barbus* | *Barbus* |
| *kersin* | *Barbus* | *Luciobarbus* |
| *kosswigi* | *Cyclocheilichthys* | *Carasobarbus* |
| *lacerta* | *Barbus* | *Barbus* |
| *luteus* | *Systomus* | *Carasobarbus* |
| *miliaris* | *Barbus* | *Barbus* |
| *mursa* | *Cyprinus* | *Luciobarbus* |
| *sharpeyi* | *Barbus* | *Mesopotamichthys* |
| *sublimus* | *Barbus* | *Carasobarbus* |
| *subquincunciatus* | *Barbus* | *Luciobarbus* |
| *urmianus* | *Barbus* | *Barbus* |
| *xanthopterus* | *Luciobarbus* | *Luciobarbus* |

There are also conflicting views on the validity and synonymy of several nominal "*Barbus*" species. An extensive comparison of these views is not given here (see, for example, Myers (1960), Karaman (1971), Almaça (1983, 1984a, 1984b, 1986, 1990, 1991, 1992, 1994), Krupp (1985c), Howes (1987), Doadrio (1990), Eschmeyer (1990), Berrebi (1995), Berrebi *et al*. (1996), Tsigenopoulos and Berrebi (2000), and Berrebi *et al*. (2014)). The latter paper gave an overview of the genus *Barbus sensu lato* and progress in understanding the taxa involved.

Author’s views conflicted, even when examining the same material. Problems included:- the low number of specimens examined (Almaça (1984a, 1986) for example, examined 11 nominal taxa relevant to Iran in detail but averaged only about six specimens per taxon, often from a single locality or outside Iranian waters); a wide range in size of individuals of species being compared making age related changes difficult to assess (denticles in the dorsal fin are often lost with age, barbels are shorter, body shape changes, lip development varies, etc.); the possibility of sexual dimorphism; possible variation between populations; ecomorphs being recognised as genera (e.g., *Luciobarbus* was recognised by having 4, as opposed to 5, teeth in the outer pharyngeal tooth row; *Bertinius* was founded on this condition and development of molar teeth for crushing molluscs - but this may have risen independently in response to an ecological opportunity (see Krupp (1985c)); paedomorphosis and independent origins from a generalised form in different sites (Mina *et al*., 2001); a lack of a wide range of new material; and not all types are extant and some that do exist are in poor condition. If this were not complication enough, “*Barbus*” species are prone to hybridisation with other "*Barbus*" species and even other genera, further confusing the resolution of the issue. Almaça (1990) cited a hybridization rate of 5.5-6.0% in “*Barbus*” of the Iberian Peninsula, higher under changed ecological conditions such as the building of dams. However, recent molecular studies have greatly clarified the genera and species formerly encompassed by *Barbus sensu lato*.

The status of *Bertinius longiceps persicus* Karaman, 1971 described from the “Karun b. Ahvaz, Persien” (= Karun River at Ahvaz, Khuzestan) on a single specimen is uncertain (lateral line 56-58, gill rakers 22, subterminal mouth, very short barbels, head somewhat higher and suddenly narrowing compared to the type subspecies of the Jordan and Orontes basins, acuminate snout, dorsal fin margin concave). It is not “*Barbus*” *longiceps* (F. Krupp, *in litt*., 1986). The holotype is in the Zoologischen Instituts und Zoologischen Museums der Universität Hamburg (ZMH H2509).

Barbels are medium to large fishes living on the bottom of a wide range of habitats from lakes to fast-flowing montane rivers (Gante, 2011) although some may inhabit ponds and springs. They feed on a wide variety of organisms, some on other fishes. Most show migrations for spawning and may move between rivers and marshes.

Mostafavi and Kambouzia (2019) modelled potential distribution of *Barbus* in Iran based on eight environmental variables, namely slope, bankfull width, elevation, maximum, minimum and mean air temperature, range of air temperature, and annual precipitation. The most important were mean air temperature, annual precipitation and elevation. The data could be used to identify both critical habitats and habitats suitable for translocation of threatened populations.

The roe or eggs of species in these genera have been implicated in poisoning (Halstead, 1967-1970) and should be avoided (see under the genus *Schizothorax* for more information on egg poisoning). Fish should be carefully cleaned in the spawning season to remove the eggs and ensure against contamination of flesh. Severe cases of egg poisoning in other species have resulted in death. Sykes (1927) however, in his account of the travels of Sir John Chardin in Persia (first published in 1686) quotes “*Barbel*.... the Spawn of them especially is dangerous, being a certain and a violent Vomit, by Reason that the Sun never shines on that Fish, and that it breeds in raw Waters; or because they take it with the *Nux Vomica* or the Vomiting Nut”. Najafpour and Coad (2002) reported a case of roe poisoning from eggs of *Carasobarbus luteus*.

A species called soleymani, possibly a “*Barbus*” species, was considered to be on the

verge of extinction in the Gamasiab River of the Tigris River basin, through pollution, overfishing, dam building, aquaculture, and introduction of exotics (www.iranmania.com, downlaoded 29 December 2006). "*Barbus*" species in Khuzestan are thought to be the intermediate hosts of Heterophyidae flukes found in humans and carnivores (Massoud *et al*., 1981).

Sharifi *et al*. (2008) recorded a *Barbus* sp. as a predator on the eggs and larvae of the Luristan newt, *Neurergus kaiseri*, in highland streams of the southern Zagros Mountains, Lorestan (this could be *Barbus lacerta* or possibly a *Luciobarbus* species). This newt is known from only four streams and is classified by the IUCN as Vulnerable (downloaded 24 October 2019).

Kazeraani (1994) gave a short account of Iranian "*Barbus*" species in Farsi. The common names in Farsi for these fishes generally are sos, ses or sas mahi, meaning unknown but referring to "*Barbus*", and zardehpar, zardek or zardak and ourange or ourenge (in reference to yellow or orange colourations, probably of the fins).

The origin and movements of "palaearctic" or Euro-Mediterranean "*Barbus*" species in Southwest Asia have been examined by Banarescu (1976, 1977) and Almaça (1984b, 1988, 1990) and these works should be consulted for further details. These works are not cladistic analyses but groupings of species based on morphological similarities and may be subject to criticism on this account.

The origin of the genus "*Barbus*" according to these authors lies in East Asia and reached the Euro-Mediterranean region by a Siberian route. "*Barbus*" became extinct in northern East Asia, Siberia and northern Europe when the climate cooled during either the Pliocene or the Quaternary. Europe was colonised during the Oligocene and it is from Europe through Anatolia that Southwest Asia received many of its "palaearctic" "*Barbus*". This route of entry probably did not occur before the Pliocene because the Syrian-Iranian Sea, the last connection between the Tethys Sea and the Indian Ocean, blocked passage of primary freshwater fishes into what is now Iran and adjacent regions although a connection between a Balkan-Aegean-Anatolian landmass and Iran was possible during the early Miocene (20-17 MYA). A marine transgression 16.8-11.8 MYA flooding the eastern Paratethys and the rise of mountain barriers led to independent evolution of "*Barbus*" in the Balkan-Aegean-Anatolian landmass and in the Iranian Plateau. During the late Miocene the eastern marine connection of Paratethys closed (11.8-10.5 MYA) allowing an exchange of "*Barbus*" between Iran and Anatolia, continuous from that time. The Paratethys became an intracontinental sea, the Sarmatian Sea, with a basin encompassing the present Black, Caspian and Aral seas and neighbouring low-lying areas (Bianco, 1990). The Sarmatian Sea freshened as large rivers entered it during the late Miocene and Pliocene, facilitating dispersal of freshwater fishes. A second route of entry for "*Barbus*" to northern Iran was via southwestern Siberia and the Aral Sea basin during the early to middle Oligocene. Bănărescu and Bogutskaya in Bănărescu and Bogutskaya (2003) agreed on an East Asian origin for "*Barbus*", dispersing across Siberia and Western Asia. The group split into two branches, one forming *Barbus sensu stricto* and using a dispersal route north of the Ponto-Caspian basin and reaching Western Europe, and another (*Luciobarbus*) dispersing across the present-day Mediterranean Sea (see above in discussion of Berrebi and Tsigenopoulos in Bănărescu and Bogutskaya (2003) and Tsigenopoulos *et al*. (2003) for listing of nominal taxa relevant to Iran in these branches or groups).

An overview of "*Barbus*" systematics restricts the genus to Europe, Southwest Asia and Northwest Africa (Berrebi *et al*., 1996). *Barbus sensu stricto* is recognised as a lineage which

shares morphological characters, has an ancestral tetraploid origin of 2n = 100, and has similar karyotypes, biochemical markers, and parasites. Genetic studies indicated four groups of species, namely West European and Ponto-Caspian, Iberian, Northwest African, and Levantine. Iberian barbels are found in Spain and Portugal and along within the Northwest African barbels share no species with Iran. The West European and Ponto-Caspian barbels include *B. brachycephalus* (= *caspius* in Iran), *B. capito* and *B. mursa*, and the Levantine barbels include *B. barbulus*, *B. cyri*, *B. esocinus*, *B. lacerta*, *B. pectoralis*, *B. rajanorum*, *B. scincus*, *B. subquincunciatus* and *B. xanthopterus*. The authors make no comments on the validity of these nominal species and only *B. brachycephalus* (= *caspius*) has been examined in detail for karyotypes and/or nuclear markers. This work is continuing and the authors advocated various methods. They noted that accurate descriptions of many taxa are lacking and that morphology is still the fastest and most cost-efficient way to identify species. Accurate identification is the foundation for all other studies.

Machordom and Doadrio (2001), using ATPase 6 and 8 and cytochrome *b*, found differentiation in "*Barbus*" *capito* and "*B*". *brachycephalus* (= *caspius*) in the Plio-Pleistocene. A clade of the subgenus *Luciobarbus* was found for species from the Caucasus (as above), Greece and North Africa compared to the Iberian Peninsula, isolation having occurred after the Messinian salinity crisis 5.5 MY ago when the Iberian Peninsula broke away from Africa.

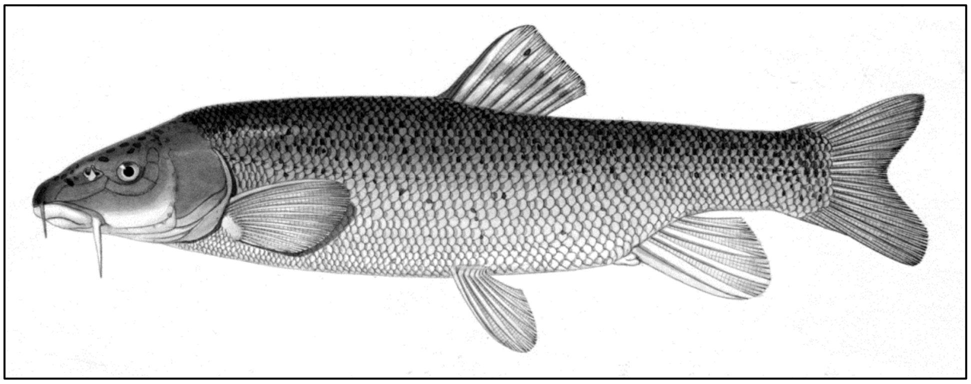
Berrebi *et al*. (1996) recommended that *Barbus*-like species which cannot be allocated to a clearly defined genus should be placed in a genus called *'Barbus'*, surrounded by single quotation marks, until the systematic position is elucidated. Readers are referred, for further information, to the accounts under the various genera herein now distinguished from *Barbus sensu lato*.

Jouladeh-Roudbar *et al*. (2016), in a conference presentation, compared fish from the Alvand, Sepidbarg (= Sefid Barg) and Sivand rivers of the northern Iranian Tigris River basin using meristic and morphometric characters and concluded that the Alvand population belongs to an undescribed taxon. Keivany *et al*. (2018) examined body shape variation in *Barbus sensu stricto* from the Caspian Sea, Lake Urmia and Tigris River basins concluding they were separate genetic and morphological stocks (although noting habitat-associated morphological divergence).

The following table summarises some key distinguishing characters of the Iranian species of *Barbus sensu stricto*.

| Species/ Characters | Lateral line scales | Middle pad lower lip | Anal fin margin | Upper lip, in head length | Gular region | Distribution |
|---|---|---|---|---|---|---|
| *B. cyri* | 50-87 | Weakly-developed | Convex | Wide, 7-9% | Rectangular | Caspian Sea and Lake Urmia |
| *B. karunensis* | 59-70 | Well-developed | Straight | Narrow, 4-6% | Rectangular | Karun River, Tigris River |
| *B. lacerta* | 52-67 | Absent to present | Straight | Narrow, 4-6% | Triangular | Tigris River |
| *B. miliaris* | 69-90 | Variable | Straight | Narrow, 4-6% | Rectangular | Namak Lake |
| *B. urmianus* | 64-85 | Well-developed | Straight to slightly concave | Intermediate, 4.5-7.5% | Rectangular | Mahabad River, Lake Urmia |

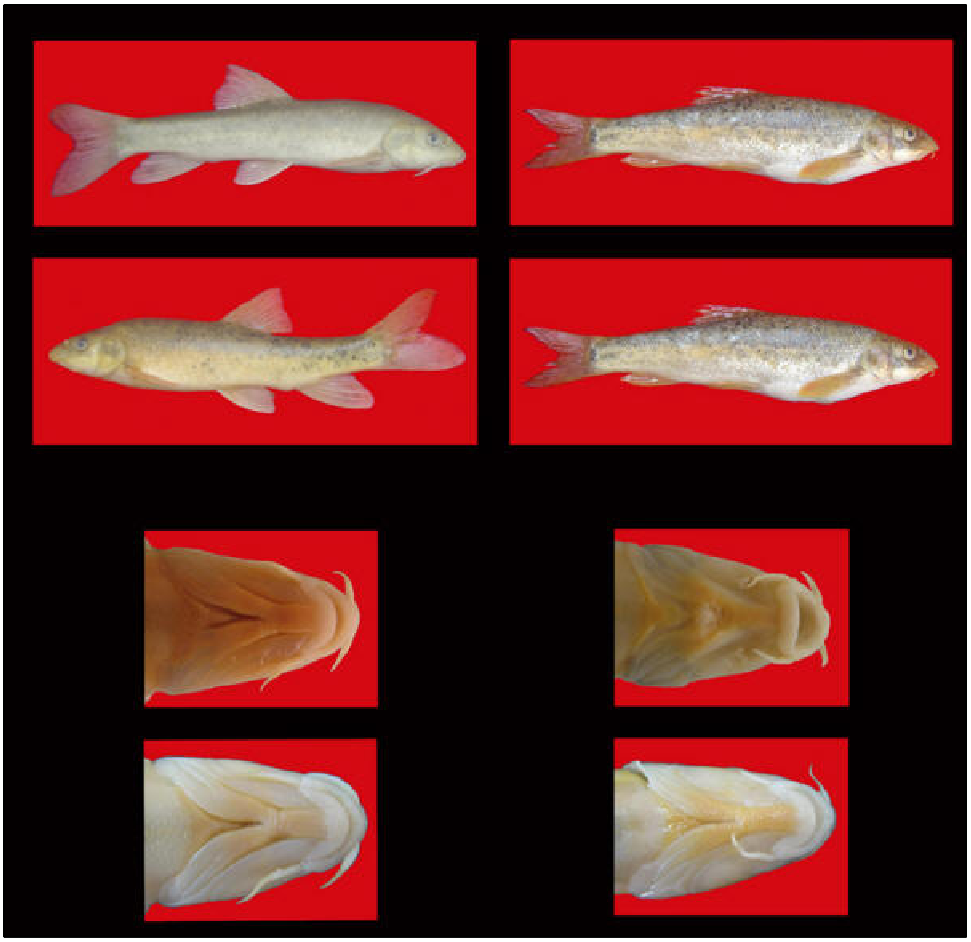
## ***Barbus cyri***
De Filippi, 1865



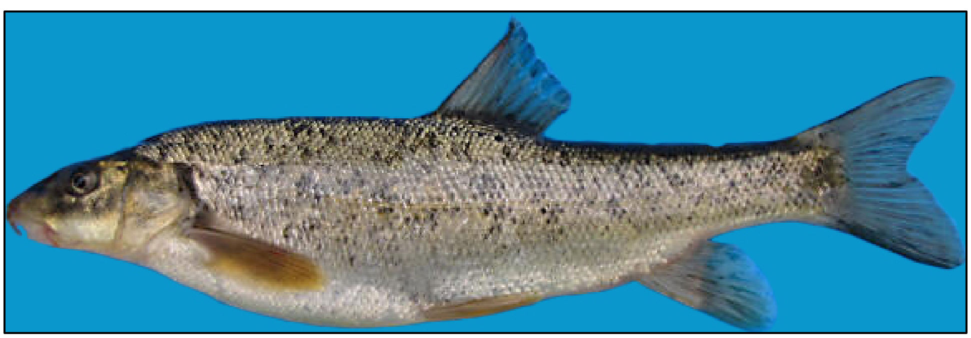
*Barbus cyri*, 31.8 cm total length, ZISP 14744, Georgia, Taparavani (= Paravani) River at Akhalkalaki (upper Kura River basin), after Berg (1948-1949).

*Barbus cyri*, Kordestan, Saqqez River, Lake Urmia basin, Atabak Mahjoorazad.

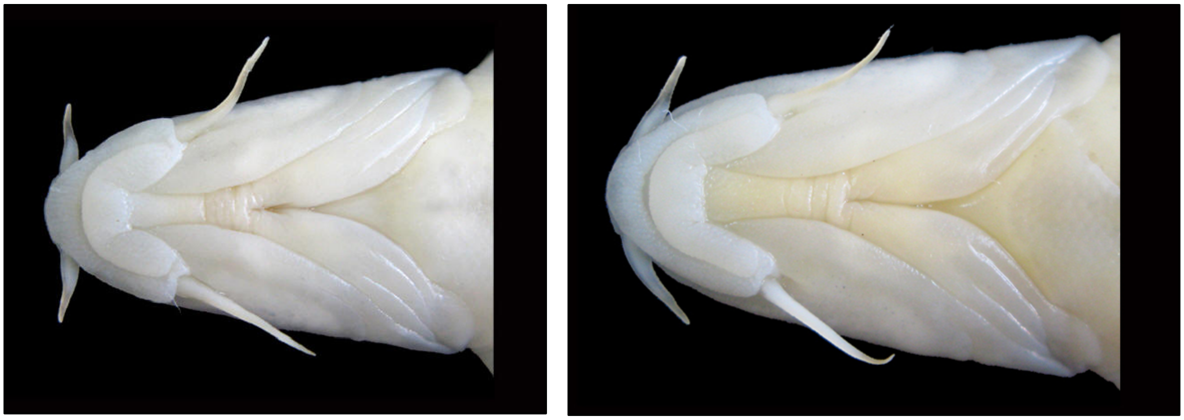
*Barbus cyri*, Kordestan, Saqqez River, Lake Urmia basin, Atabak Mahjoorazad.



*Barbus cyri*, Caspian Sea basin, Atabak Mahjoorazad.



*Barbus cyri*, Gilan, Haviq River, Caspian Sea basin, August 2011, Keyvan Abbasi.



*Barbus cyri*, Lake Urmia basin, Atabak Mahjoorazad.

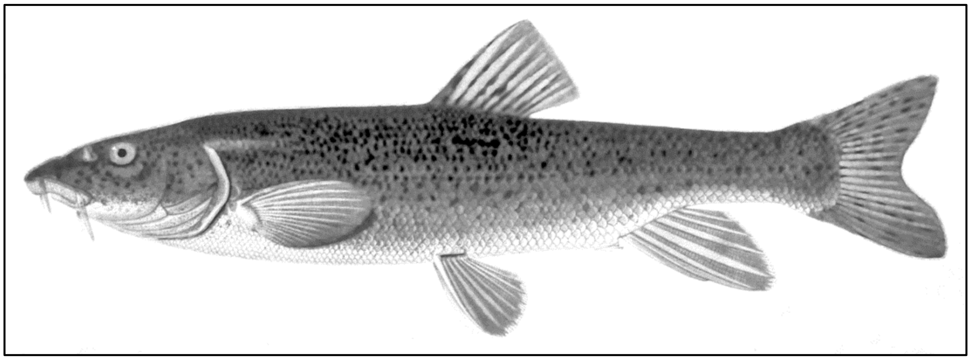
**Common names.** Sos or sas mahi Kura (= Kura ? fish; meaning of sas or sos unknown but referring to "*Barbus*"), orenj (in reference to orange fins).

[Kur sirbiti in Azerbaijan; murtsa, muruz, muruza or murza in Transcaucasia generally; mursa in Armenia (although mursa variant terms would seem to more appropriate for *Luciobarbus mursa*); Kurinskii usach or Kura barbel in Russian; Bıyıklı balık, Bekir Kura bıyıklı balığı in Turkish (Kaya *et al*., 2016, 2020; Çiçek *et al*., 2020); Kura barbel].

**Systematics.** *Barbus cyri* was described from the "Kur presso Tiflis" (= Kura River near Tbilisi, Georgia).

Synonyms are *Barbus caucasicus* Kessler, 1877 from the Kura and Aras rivers and tributaries, Azerbaijan, *Capoeta fundulus* var. *toporovanica* Kamensky, 1897 described from the "Toporavan See" (= Lake Paravani or Taparavani at 41°26'N, 43°48'E, in the upper Kura River basin of Georgia) (no types found), *Barbus angustatus* Kamensky, 1899 described from the "Kura, bei Borshom", Georgia (holotype ZISP 10416) and *Barbus armenicus* Kamensky, 1899 described from the "See Tschaldyr-göll, 6522' und den Kars-tschai" (Çıldır Gölü, 6522' and the Kars-chai, Turkey) (lectotype ZISP 5198, three paralectotypes in the Caucasian Museum but locality unknown), *Barbus bortschalinicus* Kamensky, 1899 described from the "schwarze Flüsschen (Das schwarze Flüsschen fällt in die Bortschala, rechter Zufluss des Chram, Nebenfluss der Kura) (tschernaja rjetschka)" (Black River (the Black River falls into the Borchala, right tributary of the Chram, tributary of the Kura (Black River), Georgia (no types found), *Barbus cyri* var. *chaldanica* Kamensky, 1899 described from the "Andshigan-tschai unweit Chaldan" (Andshigan-chai not far from Khaldan, Azerbaijan;), *Barbus cyri* var. *tiflissica* Kamensky, 1899 described from the "Kura bei Tiflis", Georgia, *Barbus sursunicus* Kamensky, 1899 described from "Sursuna in dem Flüsscheu (*sic*) Kara-tschai, Nebenfluss der Kura, oder ihrem Zuflusse, erbeutet in einer Höhe von ca 3200', zwischen den Seen Tschaldyr-göll und Tuman-göll, dass kleinere aus dem Flüsschen Abastuman-tschai" (Sursuna in the river (*sic*) Kara-chai, tributary of the River Kura, or its tributary, captured at an altitude of ca. 3200' between the lakes Çıldır Gölü and Tuman Gölü, that smaller from the River Abastuman-chai; presumably this is the Kars-chai, tributary to the Aras River and thence the Kura River, Turkey (later in the same article this species is spelt *zurzunicus*) (no types found). Type localities from Kamensky (1899) are, obviously, taken from the German text; there is also an accompanying and preceding Russian text with localities in Latin and Russian that are very similar, although in some cases abbreviated. Some Kamensky types are illustrated but are of poor quality, being

photographs. Levin *et al*. (2019) sampled type localities of *B. bortschalinicus* and *B. toporovanicus* and their genetic data confirmed synonymy.



*Barbus sursunicus*, lectotype, 26.0 cm total length, ZISP 14740,
Azerbaijan, Zurzuna River, basin of the Aras River, after Berg (1948-1949).

Tortonese (1940), Eschmeyer *et al*. (1996) and the *Catalog of Fishes* (downloaded 30 May 2018) listed the holotype of *Barbus cyri* as in the Istituto e Museo di Zoologia della R. Università di Torino (MZUT N.690). No types have been found for the two varieties of *Barbus cyri* listed above.

The lectotype of *Barbus armenicus*, as established by Berg (1948-1949: Fig. 452), is in the Zoological Institute, St. Petersburg under ZISP 5198 with three paralectotypes (Eschmeyer *et al*., 1996).

The lectotype of *Barbus sursunicus* is in the Zoological Institute, St. Petersburg under ZISP 14740 as established in Berg (1948-1949: fig. 451, see above).

Bianco and Banarescu (1982) placed specimens from the Aras River near Maku in *Barbus cyclolepis cyri* De Filippi, 1865, incorrectly as *B. cyclolepis* Heckel, 1839 is from eastern Europe, the Aegean and Black Sea basins.

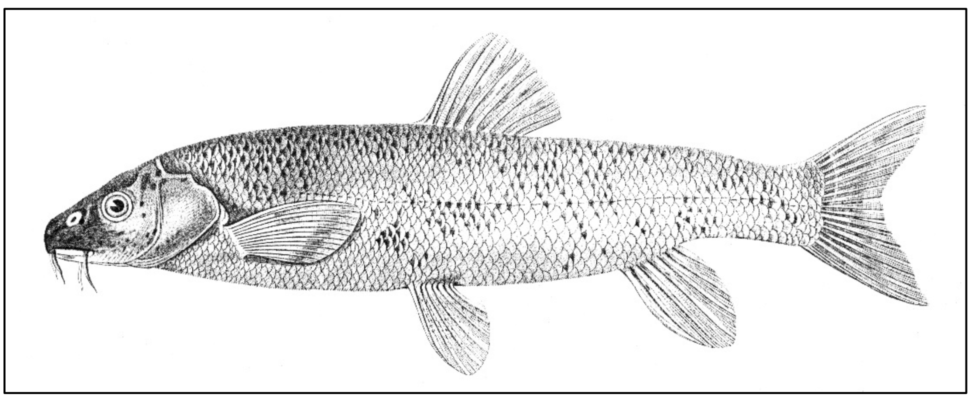
Abdurakhmanov (1962) compared fish from the Aras and Kura river basins and the Lenkoranchai. Lenkoran fish had fewer scales, longer head length and depth, greater maximum body depth, greater anal fin height, longer pelvic and ventral fins, a longer lower caudal fin lobe, a shorter caudal peduncle length, a smaller eye, and a shorter interorbital width than Kura and Aras fish; Lenkoran fish had a longer predorsal distance, greater caudal peduncle depth, and greater dorsal fin height than Kura fish though Aras fish were the same; Lenkoran fish had the dorsal fin base and postorbital distance less than in Aras, but not Kura, fish. No taxonomic distinction was made for these variations.

Gorjian Arabi *et al*. (2009) found no major differences in meristic and morphometric characters of a population in the Kesilian (= Kaslian) River sampled in different seasons. Eagderi (2014) and Zamani Faradonbeh *et al*. (2014, 2014, 2015) found morphometric differences between fish from rivers in the Sefid River basin and these were attributed to environmental conditions and geographical isolation. Zamani Faradonbe and Eagderi (2016) reported differences in morphology (body and caudal peduncle depth, head length) between fish separated by the Sangban Dam on the Taleghan (= Taleqan) River in the Sefid River basin. Jamali Ashtiani *et al*. (2016) compared fish (as *B. lacerta*) from the Caspian Sea (Kloraz, Taleqan and Tutkabon rivers), Lake Urmia (Zarrineh River) and Tigris River (Hamill River) basins and found differences in morphometric characters between rivers within a basin and between basins, with Caspian and Tigris populations in a distinct group. Zare Shahraki *et al*.

(2017) also found morphometric and meristic differences between fish from the Sefid, Sardab and Tajan rivers attributed to habitat variation. Radkhah *et al*. (2016) examined 300 fish from the Zarrineh River and found differences in body and caudal peduncle depth between upstream and downstream samples, attributed to differences in water flow velocity and river discharge.

Jalili *et al*. (2015) described the osteology of fish from the Sefid River and compared it to published reports on fish from the Tigris River and Lake Urmia basins by Razavipour (2013) and Jalali *et al*. (2015). *B. cyri* can be distinguished from *B. lacerta* by having three pharyngobranchials (as opposed to two), a consumptive neural spine of the second centrum, an hypural plate formed from 5 vertebrae (as opposed to 4), having the third and fourth vertebrae with posteriorly positioned neural spines, and neural prezygapophyses of the fourth vertebra absent. Lake Urmia fish had the neural arch of the fourth vertebra posteriorly bent (as opposed to dorsally bent in *B. cyri* and *B. lacerta*) and there were two stays in the anal fin (as opposed to one in *B. cyri* and *B. lacerta*).

Levin *et al*. (2015, 2019) used mtDNA and nDNA markers to determine the phylogenetic relationships of Caucasian barbels. The Caspian group comprised *B. cyri* and *B. ciscaucasicus* Kessler, 1877 (the latter has not been recorded from Iran and is found from the western drainages of the Caspian Sea south to the Pirsaat River of Azerbaijan (Gandlin *et al*., 2017)) with the Sevan barbel *B. goktschaicus* Kessler, 1877, the latter a synonym of *B. cyri* (Kuljanishvili *et al*., 2020). The “Caspian” group also included *B. lacerta*. Black and Caspian Sea lineages split early after the colonisation of the Ponto-Caspian basin during the Lower Miocene 9.45 MYA (Levin *et al*., 2019).



*Barbus goktschaicus*, syntype, after Kessler (1877).

Khaefi *et al*. (2018) used mitochondrial D-loop sequences to study *Barbus* in northern Iran, ascribing all Caspian Sea basin specimens to *B. cyri* and noting different levels of isolation between populations there due to ecological and anthropological factors. Fish from the Kalibar River showed high genetic diversity and this locality was proposed as a diversification centre for this species in the southern Caspian Sea basin. Fish from the Lake Urmia basin formed a western lineage in contrast to the northern lineage in the Caspian Sea basin. The genetic distance between the Caspian and Urmia populations was much lower than other individuals and taxa from the genus *Barbus* and a close relationship existed (see also Khaefi *et al*. (2017)).

**Key characters.** Khaefi *et al*. (2017) distinguished this species from other Iranian *Barbus* species by having a convex posterior anal fin margin (versus straight) and a wide upper lip (7-9% head length versus 4-6%). Distribution is also key.

**Morphology.** Berg (1948-1949) noted the extremely wide variation in body depth, fin and barbel lengths, the number of dorsal fin denticles and scale count. The body is fusiform

and elongate and somewhat compressed. The back in front of the dorsal fin is flat or slightly compressed. The head profile is convex and may have a groove before the nostrils, well-developed in larger fish and only a slight groove in smaller ones. The head profile is straight in males, steeply descending in front of the nostrils in females (Berg, 1948-1949) but Bogutskaya in Bănărescu and Bogutskaya (2003) found some males with a hump on the snout. Morphology is quite variable. Fish in northern parts of the Lake Urmia basin have a longer and more flattened head than those from the south (Motamedi *et al*., 2014). The mouth is inferior, moderate in size with moderate to thick tuberculate lips, the lower one with or without a median lobe, variably developed, and when present the lobe is weak. However, the lip does have a central area that is thicker and distinct from the lips laterally in small fish. Bogutskaya in Bănărescu and Bogutskaya (2003) gave illustrations of lower lip development and variations in head shape. The lower jaw may have a thin horny cover. The barbels are thick at the base and taper towards the tip, with the anterior one reaching back to the nostril level and the posterior one to the middle of the eye or to the preopercular. Barbels are shorter in females, anterior ones not reaching the nostrils (Berg, 1948-1949). The dorsal fin margin is rectilinear or slightly concave, rarely slightly convex, and oblique or sloping in relation to the back (Berg (1948-1949) states this fin is never emarginate). The depressed dorsal fin does not reach back to the level of the anal fin origin. The dorsal fin origin is slightly in front of, over or behind the pelvic fin origin level. The last unbranched dorsal fin ray is moderately thickened with moderate to long denticles posteriorly, denticles being on up to 72% of the ray length. The extent of denticles may be size-related with more on smaller fish; the extent is quite variable. Berg (1948-1949) counted up to 63 denticles, noting they may be absent in larger fish. Bogutskaya in Bănărescu and Bogutskaya (2003) counted 20 to 65 denticles. The anal fin margin is rounded or convex. The tip of the anal fin does not reach, or reaches, to the middle of the distance between the anal fin insertion and the lower caudal fin origin, or to the procurrent caudal fin rays, the latter usually being females. The lower lobe of the caudal fin is more or less rounded and the fin is slightly to moderately forked. The length of the caudal peduncle is 1.7-2.3 times longer than deep, the snout is short, its length 44-47% of body depth at the dorsal fin origin, the maxillary barbel is 12-30% head length, not reaching to the posterior eye margin, the gular region is rectangular, eye diameter is 2.5-2.9 times in snout length, and the median pad of lower lip is wide and shallow.

Dorsal fin unbranched rays 3-5, usually 4, branched rays, 7-9, usually 8, anal fin branched rays 3-4, branched rays, 5-6, usually 5, pectoral fin branched rays 13-19, and pelvic fin branched rays 7-10. Lateral line scales 50-87 and predorsal scales 24-34 (mode 29). Berg (1948-1949) gave 57-73 lateral line scales, Abdurakhmanov (1962) gave 55-72, Bogutskaya in Bănărescu and Bogutskaya (2003) gave 54-75, A. Mahjoorazad (pers. comm., 29 January 2007) gave 57-87 and Khaefi *et al*. (2017) gave 50-76, while my counts (see below) have a wide range of 53-87. Scale count mean (70.03) is significantly higher in the Lake Urmia basin than in the Caspian Sea (60.43) (Motamedi *et al*., 2014) and Khaefi *et al*. (2017) found means of 66.8 and 59.4. There are 3-6 (mode 5) scale rows between the tip of the anal fin and the base of the caudal fin. There is a small pelvic axillary scale. Scales are horizontal ovals or rectangular in shape with a wavy anterior margin or central protuberance. Small fish have a rounded anterior margin and scales are more rounded in shape overall. The focus is sub-central anterior and radii are numerous and close on all fields and there are few to moderate numbers of circuli. Total gill rakers number 5-13, and are stout and widely spaced. Pharyngeal teeth are usually 2,3,5-5,3,2, with variants 2,3,5-5,3,1, 2,3,4-5,3,2, 2,3,5-4,4,2, 2,3,4-4,3,2, 1,3,5-5,3,2 or

3,3,5-5,4,1, slightly to obviously hooked and slightly or not serrated with a flat surface below the hook. The gut is a very elongate s-shape with 1-2 anterior loops and one posterior loop. Total vertebrae number 39-45. Nikmehr *et al*. (2016) recorded 42 vertebrae.

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(26), anal fin branched rays 5(26), pectoral fin branched rays 14(2), 15(5), 16(14) or 17(5), pelvic fin branched rays 7(6) or 8(20), lateral line scales 53(1), 54(-), 55(-), 56(2), 57(-), 58(-), 59(2), 60(1), 61(-), 62(-), 63(2), 64(2), 65(2), 66(1), 67(1), 68(-), 69(3), 70(-), 71(-), 72(1), 73(-), 74(2), 75(-), 76(2), 77(-), 78(-), 79(1), 80(-), 81(-), 82(2), 83(-), 84(-), 85(-), 86(-) or 87(1), total gill rakers 7(7), 8(7), 9(6), 10(3), 11(1), 12(-) or 13(1), pharyngeal teeth 2,3,5-5,3,2(12), 2,3,4-5,3,2(1), 2,3,4-4,3,2(3) or 3,3,5-5,4,1(1) and total vertebrae 42(7), 43(9) or 44(2).

**Sexual dimorphism.** Females have shorter barbels than males (Berg, 1948-1949) and females have longer anal and ventral fins (Bogutskaya in Bănărescu and Bogutskaya, 2003). Males are a dark gold dorsally and all fins slightly reddish with a gold iridescence when spawning (Bogutskaya in Bănărescu and Bogutskaya, 2003). Spawning females have reddish ventral and anal fins but males are redder. Gorjian Arabi *et al*. (2010) found no strong distinction between sexes in the Keselian (= Kaslian) River analysed in a principal components analysis with only one of 26 morphometric and one of 10 meristic characters being significantly different.

Male fish caught on 7 June 1978 (CMNFI 1979-0449) and 25-26 June 1962 (CMNFI 1979-0785) had minute tubercles thickly developed on the head top, sides and ventrally, a few on the operculum, lining the margin of anterior belly scales but also 1-2 tubercles in mid-scale, and on anterior flank scales numbering 1-4 becoming one tubercle on more posterior scales although most mid-flank scales lacked tubercles. Lower flank and lower caudal peduncle scales bear a tubercle. Single tubercles are usually at the mid-rear of the scale. Tubercles are also present on the back behind the dorsal fin.

Anterior back scales may have a unique tuberculation consisting of a line rather than a rounded tubercle (fish caught on 9 July 1978, CMNFI 1979-0493). The line lies centrally on the scale and extends from the margin part way along the exposed scale. Behind the dorsal fin the back scales have the central line and one on each side radiating back and up and back and down. Tubercles on the dorsal, caudal and anal fins are small and follow the fin branching. They are weak to absent on the pectoral and pelvic fins but are found on the pectoral fin unbranched ray in two rows.

**Colour.** Live fish are brownish-yellow to olive-grey, dark on the back and grey-white on the belly. The lateral line may be orange. Pectoral and pelvic fins have orange tinges. Overall colour is dark brown in preservative. Speckles are present of the body and top and sides of the head, disappearing on the lower flank. These speckles may clump together and form small to large blotches. Speckles are present on the dorsal and caudal fins or there may be few speckles but pigment along rays and on some membranes. There is some pigment on anal fin rays distally, a few elongate splotches on the pelvic rays but no pattern, and the pectoral fin has spots but also scattered melanophores along the rays. Younger fish are more brightly coloured than the adults. The peritoneum is brown.

**Size.** Attains 37.5 cm (Berg, 1948-1949) or 40.0 cm total length and 460 g (Bogutskaya in Bănărescu and Bogutskaya, 2003).

**Distribution.** This species is found in the Caspian Sea and Lake Urmia basins. In the Iranian Caspian Sea basin found in the Abhar, Alamut, Aras, Ariachay, Astara, Atrak, Babol, Balekhlu, Beyg Baghi, Chaisalman, Chalus, Divan Darreh, Gorgan, Haraz, Haviq,

Idaghamush, Kalibar, Kangar, Kargan, Kelarud, Keselian (= Kaslian), Kheyr, Kloraz, Lisar, Nowshahr, Polrud (= Pol-e Rud), Qareh Su, Qatorchay, Qezel Owzan, Sardab, Sarisu, Sefid, Selin Chay, Shafa, Shah, Shahrbijar, Shalman, Shirud, Tajan, Talar, Taleghan (= Taleqan), Tonekabon, Tutkabon, Valam and Zarem rivers, the Anzali Talab, and the Nazdik Dam on the Sefid River and the Taleghan (= Taleqan) and Arasbaran dams; and in the Lake Urmia basin in the Aji or Talkheh, Balanoosh (= Balanej), Baranduz, Biter (or possibly Bitas), Chamalton, Chamkoor (= Koor), Chamsaqez (= Saqqez), Ghale (= Qal'eh), Ghara, Ghasemlu or Qasemlu Godarkhosh, Goldar, Hasanlu, Koor, Mardog, Nazlu, Qader (or Gedar), Rozeh, Saqqez, Seroudan, Shahr, Simineh, Sufi (or Sofi), Tatavi, Urmia, Yalekhlou, Zarrineh and Zowla (= Zola) rivers, Cheragveis, Golabar and Hasanlu dams, and Guru (Guru Gol or Guru Gowl) and Ghalehchai (= Qal'eh) lakes (Günther, 1899; Laptev, 1934; Berg, 1949; Holčík and Oláh, 1992; Shamsi *et al*., 1997; Abbasi *et al*., 1999, 2005; Kiabi *et al*., 1999; Abdoli, 2000; Mirhasheminasab and Pazooki, 2003; Pazooki *et al*., 2003; Gorjian Arabi *et al*., 2009; Moradi and Eagderi, 2014; Motamedi *et al*., 2014; Zamani Faradonbe *et al*., 2014; Ghasemi *et al*., 2015; Vatandoost *et al*., 2015; Jamali Ashtiani *et al*., 2016; Babaei, 2017; Dadai Ghandi *et al*., 2017; Eagderi and Moradi, 2017; Khaefi *et al*., 2017, 2017, 2018; Eagderi *et al*., 2019; Fathi and Ahmadifard, 2019; Jouladeh-Roudbar *et al*., 2020; Shahnazari *et al*., 2020; Abbaszadeh *et al*., 2021).

**Zoogeography.** Khaefi *et al*. (2017), using DNA barcode data, found this species to be the sister group to all other Iranian species. Khaefi *et al*. (2018) regarded the origin of Iranian *B. cyri* as from the Kura/Aras River system to the west of the Caspian Sea basin in the Pleistocene. These authors also discussed evidence of gene flow between southern Caspian Sea populations, some being limited as they are separated by mountain ranges, others facilitated by flood water exchange in neighbouring watersheds. Anthropogenic factors have also affected population isolation. See also above in **Systematics**.

**Habitat.** This species is found in rivers, streams, lakes, dams and marshes. It is not migratory to the Caspian Sea but may travel some distance within a river (Bogutskaya in Bănărescu and Bogutskaya (2003). It avoids muddy bottoms and prefers sandy or stony substrates (Solak, 1977; Bogutskaya in Bănărescu and Bogutskaya, 2003). These habitats are rich in benthos, cool, with rapid currents and are well-oxygenated; however, it may congregate in slow waters where temperatures reach 26°C. Zamani Faradonbe *et al*. (2014) studied suitable habitat parameters in 33 stations on the Taleghan (= Taleqan) River of the Sefid River basin and found these were as follows from the English abstract and the Farsi abstract in parentheses (often not matching):- depth 50-60 cm (9-29 cm), river width 0-5 m (2-9 m), water velocity 0.3-0.6 m/s (0.9-9.9 m/s), slope 1.5-2.0 degrees (2.0-2.1 degrees), number of large stones (> 25 cm) (< 22 cm) fewer than four (same), average diameter of bedrock 35-20 cm (*sic*) (29-29 cm, *sic*), index of substrate 5.5-7.0 (bedding index percentage 2.0-2.7), algal cover less than 2% (same), and riparian forest (tree-shrub). The river was an excellent habitat for this fish. However, Zamani Faradonbe and Eagderi (2015) found Taleghan (= Taleqan) River fish occupied all possible habitats due to their high adaptability to a great range of environmental factors. Presence and abundance showed a rise with increasing substrate index and bed stone diameter and a decline with increasing river width and flow velocity, in contrast to *Capoeta gracilis* (= *C. razii*) (*q.v.*). Asadi *et al*. (2016) examined this species in the Tootkabon (= Tutkabon) River (Sefid River basin) and found it mostly selected upper stretches of the river with higher velocity, middle depth, lower width, bedrock substrate of boulders, average diameter of bed stones larger than 15-50 cm, grassland riparian vegetation, elevation 130-220

m, water depth 18-75 cm, channel width less than 12 m, channel slope 0.5-2.3%, and water velocity less than 0.8 m/sec. This river was an excellent habitat for this species with a habitat suitability index of 0.798. Verdipour *et al*. (2016) examined this fish at 33 station in the Taleghan (= Taleqan) River. Fish larger and smaller than 90 mm selected similar habitats including river width 2.5-7.5 m, elevation 1,400-1,600 m asl, temperature 15-16ºC and substrate with stone diameters of 24-30 cm. Smaller fish selected lower depth areas with lower river width and current velocity and a substrate with larger stones, while larger fish selected areas with deeper water and larger bed stones. Ghaitaranpour *et al*. (2018) studied the effects of a dam on the Shah River on the habitat suitability index of this species where downstream stations were more desirable. Abbaszadeh *et al*. (2021) studied the habitat preferences of fish identified as *B. lacerta* in the Zarem River of the Tajan River basin. Environmental parameters measured were depth, water velocity, and type of biotic and abiotic substrate. Fish of different ages had different preferences.

**Age and growth.** Gorjian Arabi *et al*. (2009) found a population of 281 fish in the Kesilian (= Kaslian) River had negative allometric growth in autumn and spring, positive isometric (*sic*) in winter and positive allometric in summer. In the Tajan River, 247 fish, 4.1-19.6 cm total length, showed negative allometric growth with $W = 0.0202L^{2.6787}$ (Patimar *et al*., 2012). Pourabasali *et al*. (2012) studied 206 fish, 63.01-169.6 mm total length, from the Babol River and found age groups $0^+$ to $3^+$ years with most fish in age group $1^+$. The female:male sex ratio was 1.1:1, not different from parity. Mir-Ashrafi Langroudi *et al*. (2013) examined 236 fish, 4.8-22.7 cm total length, from the Sefid River and found males had a maximum age of $3^+$ years and females $4^+$ years, the most abundant age groups were $2^+$ for males and $3^+$ for females, the male:female sex ratio was 1:1.13, not significantly different from a 1:1 ratio, length-weight relationships were $W = 0.0054TL^{3.1628}$ for males and $W = 0.0036TL^{3.3244}$ for females (both positively allometric), the von Bertalanffy growth function was $L_t = 17.86(1-e^{-0.55(t+0.939)})$ for males and $L_t = 23.94(1-e^{-0.36(t+0.94)})$ for females, and greatest spontaneous growth for both sexes was between ages 1 and 2. Esmaeili *et al*. (2014) gave a *b* value for 18 fish from the Caspian, 9.0-17.0 cm total length, as 3.064. Zamani Faradonbeh *et al*. (2014) gave a length-weight relationship of $W = 0.00001L^{2.8592}$ for 275 fish, 3.09-20.96 cm total length, from the Taleghan (= Taleqan) River, and $W = 0.00003L^{2.768}$ for fish upstream of the Taleghan (= Taleqan) Dam and $W = 0.00002L^{2.7987}$ for fish downstream, the latter having better growth. Aazami *et al*. (2015b) gave a *b* value of 2.72 for 96 fish, 2.93-7.14 cm total length, from the Tajan River. Vatandoost *et al*. (2015) caught 234 fish from the Tajan River identified as *Barbus lacerta* and found four age groups ($0^+$ to $3^+$ years) with a gender ratio of female to male 1.8:1, a mean condition factor estimated at 1.12 for males and 1.16 for females, and a mean hepatic index for males and females 1.16 and 1.12, respectively. Zamani Faradonbe *et al*. (2015) found a *b* value of 2.966 and a condition factor (K) 0.898 for 40 fish, 5.33-17.57 cm total length, from the Taleghan (= Taleqan) River. Zamani Faradonbeh *et al*. (2015) found a *b* value of 3.0078 (isometric growth) and a condition factor of 0.847 for 70 fish, 50.7-146.97 mm total length, from the Tutkabon River. Asadi *et al*. (2017) gave a *b* value of 2.615 for 67 fish, 5.1-13.5 cm total length, from the Shahrbijar River, Gilan with a total length condition factor of 0.95.

Tahmasebi *et al*. (2014b) found an average total length of 81.95 mm and average weight of 8.13 g for Lake Urmia fish. The length-weight relationship was $W = 0.0004L^{2.2141}$ indicating negative allometric growth. Radkhah and Eagderi (2015a) gave a *b* value for 40 fish from the Zarrineh River, Lake Urmia basin, 6.6-17.1 cm total length, as 2.85, negative

allometric growth. Condition factor was 1.011.

Solak (1989a) examined a population of this species in the Aras River in Turkey and found up to 5 age groups. Abdurakhmanov (1962) recorded 5 years as life span in Azerbaijan. Çalişkan *et al*. (1999) also found 5 age groups in Çıldır Lake, Turkey (for *Barbus plebejus*, probably this species). Fish in age group 2 dominated and the largest fish attained 320 mm and 550 g. Maturity was attained at 2 years for males and 3 years for females (Bogutskaya in Bănărescu and Bogutskaya, 2003).

**Food.** Abdoli (2000) listed Plecoptera, Ephemeroptera and Chironomidae. Algae were also consumed along with terrestrial insects such as grasshoppers and dragonflies (Bogutskaya in Bănărescu and Bogutskaya, 2003). This fish does not feed in winter except in water bodies with high temperatures (Bogutskaya in Bănărescu and Bogutskaya, 2003).

**Reproduction.** A fish caught on 9 July 1978 in the Tajan River had eggs up to 1.7 mm in diameter (CMNFI 1979-0493). However, Mir-Ashrafi Langroudi *et al*. (2013) found Sefid River fish had a reproduction period of April-June, peaking in May. Pourabasali *et al*. (2012) found Babol River fish had a mean egg diameter of 0.57 mm, mean absolute fecundity was 4,360 eggs (range 624-8,250) and relative fecundity was 140.44 in the abstract and 208.86 in Table 3 (range 17.59-647.05). The mean gonadosomatic index (GSI) for females was 2.45 and for males 2.61, and mean condition factor was 1.17 for females and 1.12 for males. The highest GSI was in April and spawning extended from March to May. Vatandoost *et al*. (2015), for their Tajan River sample, found egg diameter ranged from 0.08 to 1.08 mm, mean 0. 54 mm, absolute fecundity ranged from 206 to 8,689 eggs, mean absolute fecundity was 3,876,and the mean gonadosomatic index for males and females was 2.34 and 2.48, respectively.

Eggs number up to 19,680 and a diameter of 2.3 mm in Azerbaijan (Abdurakhmanov, 1962; Bogutskaya in Bănărescu and Bogutskaya, 2003). Spawning may occur 2-3 times in a season judging by oocyte sizes in mature ovaries and occurs from the end of April to August, varying with locality, once temperatures reach 14°C, ceasing if the temperature exceeds 20°C (Bogutskaya in Bănărescu and Bogutskaya, 2003).

**Parasites and predators.** Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Neoechinorhynchus rutili* from fish in Sarisou River of West Azarbayjan Province. Molnár and Jalali (1992) recorded the monogeneans *Dactylogyrus carpathicus* and *D. linstowi* from *Barbus plebejus*, presumably this species, in the Sefid River. Shamsi *et al*. (1997) reported *Clinostomum complanatum*, a parasite causing laryngo-pharyngitis in humans, from *Barbus barbus plebejus*, presumably this species in Iran. Masoumian *et al*. (2003) recorded *Myxobolus valdogeli* while Pazooki *et al*. (2003) recorded *Rhabdochona hellichi*, *Bothriocephalus gowkongensis*, *Pseudocapillaria tomentosa*, *Allocreadium isoporum* and *Paradiplozoon homoion*, all reports from fishes captured in the Tajan and Zarem rivers of Mazandaran. Pazooki *et al*. (2005) recorded *Trichodina perforata* from this species in waterbodies of Zanjan Province. Pazooki *et al*. (2006) recorded the monogeneans *Dactylogyrus goktschaicus* and *Gyrodactylus* sp. from this fish in Zanjan Province. Barzegar *et al*. (2008) recorded the digenean eye parasite *Diplostomum spathaceum* from this fish in Iran. Barzegar and Jalali (2009) reviewed crustacean parasites in the Caspian Sea basin of Iran and found *Ergasilus* sp. and *Lernaea* sp. on this species. Yakhchali *et al*. (2011) recorded the acanthocephalan *Neoechinorhynchus* sp. from *Barbus* sp. in the Zarrineh River of the Lake Urmia basin, concluding that the fish were not suitable for pond cultivation because of the likelihood of severe economic losses from the parasite. Barzegar *et al*. (2018) reported the monogenean *Gyrodactylus ctenopharyngodonis* from fish identified as *B. lacerta* from the

Talar River, Mazandaran.

**Economic importance.** Not commercially important although it does provide sport in mountain areas of the former U.S.S.R. (Bogutskaya in Bănărescu and Bogutskaya, 2003)

**Experimental studies.** Doustdar *et al*. (2018) found that the highest level of copper contamination in a study of Aras River fish was found in this species at 13.6 µg/g dry weight muscle tissue.

**Conservation.** Kiabi *et al*. (1999) considered this species (as *B. lacerta*) to be near threatened in the south Caspian Sea basin according to IUCN criteria. Criteria included sport fishing, medium in numbers, habitat destruction, widespread range (75% of water bodies), present in other water bodies in Iran, and present outside the Caspian Sea basin. Mostafavi (2007) listed it as near threatened in the Talar River, Mazandaran. Endangered in Turkey but this status includes *B. lacerta* populations (Fricke *et al*., 2007). Listed as of Least Concern by Jouladeh-Roudbar *et al*. (2020) because of its wide distribution and presence in other countries.

**Sources.** Iranian material:- CMNFI 1970-0557, 8, 23.0-30.6 mm standard length, West Azarbayjan, Shahr Chay (ca. 37º27'N, ca. 44º55'E); CMNFI 1970-0558, 6, 28.2-53.1 mm standard length, West Azarbayjan, Qasemlu Chay (ca. 37º21'N, ca. 45º09'E); CMNFI 1970-0559, 9, 39.7-114.3 mm standard length, West Azarbayjan, Baranduz Chay (ca. 37º25'N, ca. 45º10'E); CMNFI 1979-0449, 2, 85.7-92.2 mm standard length, Ardabil, river 18 km from Khalkhal (ca. 37º42'N, ca. 48º27'E); CMNFI 1979-0452, 2, 42.7-47.0 mm standard length, East Azarbayjan, Qezel Owzan River 6 km from Mianeh (37º23'N, 47º45'E); CMNFI 1979-0468, 7, 30.9-96.1 mm standard length, Mazandaran, Haraz River (36º14'N, 52º22'E); CMNFI 1979-0493, 3, 47.4-111.7 mm standard length, Mazandaran, stream in Tajan River drainage (36º19'N, 53º23'E); CMNFI 1979-0785, 2, 115.7-134.8 mm standard length, West Azarbayjan, Shahr Chay (37º27'N, 44º55'E); CMNFI 1979-0786, 1, 84.1 mm standard length, East Azarbayjan, Guru Lake (37º55'N, 46º42'E); CMNFI 1993-0136, 1, 108.9 mm standard length, Mazandaran, Sardab River (36º39'42"N, 51º22'36"E); CMNFI 2007-0086, 1, 164.4 mm standard length, Ardabil, Qareh Su basin near Nir (ca. 38º02'N, ca. 48º00'E); CMNFI 2007-0087, 2, 35.5-48.4 mm standard length, Ardabil, Qareh Su north of Ardabil (38º22'N, 48º19'E); CMNFI 2007-0088, 2, 35.8-49.0 mm standard length, Ardabil, Qareh Su east of Lari (38º30'N, 48º03'E); CMNFI 2007-0093, 1, 30.0 mm standard length, West Azarbayjan, Qotur River south of Khvoy (38º30'N, 44º58'E); CMNFI 2007-0095, 4, 25.9-73.3 mm standard length, West Azarbayjan, Shahr Chay southwest of Urmia (ca. 37º27'N, ca. 44º56'E); CMNFI 2007-0096, 1, 33.5 mm standard length, West Azarbayjan, Qasemlu River in Baranduz Chay basin (ca. 37º25'N, ca. 45º10'E); CMNFI 2007-0097, 1, 44.8 mm standard length, West Azarbayjan, Barunduz Chay basin south of Urmia (ca. 37º16'N, ca. 45º08'E); CMNFI 2007-0103, 3, 43.6-63.7 mm standard length, Kordestan, Zarrineh River basin north of Saqqez (ca. 36º18'N, ca. 46º16'E); CMNFI 2007-0104, 2, 54.6-71.2 mm standard length, Kordestan, Zarrineh River basin south of Saqqez (ca. 36º12'N, ca. 46º18'E); CMNFI 2007-0105, 2, 31.5-48.5 mm standard length, Kordestan, Zarrineh River basin south of Saqqez (ca. 36º06'N, ca. 46º20'E); CMNFI 2007-0106, 1, 99.1 mm standard length, Kordestan, Qezel Owzan River basin near Divan Darreh (ca. 35º52'N, ca. 47º05'E); CMNFI 2007-0107, 1, 64.6 mm standard length, Kordestan, Qezel Owzan River basin near Bijar (ca. 35º54'N, ca. 47º20'E); CMNFI 2008-0137, 1, 95.1 mm standard length, West Azarbayjan, Zarrineh River (37º05'N, 45º44'E); CMNFI 2008-0158, 2, 157.2-180.0 mm standard length, Lake Urmia basin (no other locality data); USNM 205931 2, 93.0-115.4 mm standard length, West Azarbayjan, Baranduz Chay south of

Urmia (37º25'N, 45º05'E); ZMH 2634, 1, 130.5 mm standard length, Mazandaran, Haraz River (no other locality data).

**_Barbus karunensis_**
Khaefi, Esmaeili, Geiger and Eagderi, 2017

*Barbus karunensis*, 100.0 mm standard length, Kohgiluyeh and Bowyer Ahmad, Bashar River, Hamid Reza Esmaeili.

**Common names.** Sas mahi Karun, berlizem, orenj (from the orange fins).
[Karun barbel].

**Systematics.** The holotype is under ZM-CBSU G1047 (Zoological Museum of Shiraz University, Collection of Biology Department), 102 mm standard length, Kohgiluyeh and Bowyer Ahmad, Bashar River at Talegah village 10 km north of Yasuj City (30°47'27.5''N, 51°25'13.3''E) and paratypes are under ZM-CBSU G1038 (photograph captions from the original description have 1048, presumably one of these is in error), 12, 47-121 mm standard length, same locality as the holotype, ZM-CBSU D11, 8, 77-116 mm standard length, Kohgiluyeh and Bowyer Ahmad, Bashar River at Yasuj (30°40'56.2''N, 51°31'94.8''E), and FSJF 2215 (Fischsammlung, J. Freyhof), 10, 86-154 mm standard length, Chahar Mahall and Bakhtiari, Sangan Stream at Sangan (31°15.692'N, 51°17.150'E).

*Barbus karunensis*, holotype, ZM-CBSU G1047, Hamid Reza Esmaeili.


*Barbus karunensis*, paratypes, ZM-CBSU G1048, a, 100.0 mm standard length, b, 96.0 mm standard length, c,. 92.0 mm standard length, Hamid Reza Esmaeili.

**Key characters.** Khaefi *et al*. (2017) distinguished this species from other *Barbus* species in Iran by a well-developed middle pad of the lower lip (versus poorly developed or absent). The subsequently described *B. urmianus* also has a well-developed pad but more lateral line scales (64-85, mean 79.6 versus 59-70, modes 61 to 64 in *B. karunensis*) and fewer scales around the caudal peduncle (14-23, mean 19.5 versus 26-29) (Eagderi *et al*., 2019). Note that Khaefi *et al*. (2017) gave a lateral line count for *B. karunensis* of 60-70, mean 63.1 and a caudal peduncle count of 26-29, mean 27.0.

This species is also distinguished by Khaefi *et al*. (2017) from *B. cyri* by having a thin upper lip (upper lip width 4-6% head length versus 7-9% head length), and from *B. lacerta* by having a shorter anal fin, the tip of the anal fin not reaching or reaching to about the middle of the distance between the base of the last anal fin ray and the lower caudal fin origin when pressed to the body (versus reaching beyond middle, often to the caudal fin base), and there are 5-9 (mode 6) scale rows between the tip of the anal fin and the base of the caudal fin (versus 0-3, mode 2). *Barbus karunensis* is distinguished from *B. miliaris* by having 59-66+2-4 (mode 61, or to 70) scales in the lateral line (versus 69-87+3-5, but see below where *miliaris* counts reach 90), 26-29 (mode 26) scales around the caudal peduncle (versus 28-35), maxillary barbels not reaching the middle of the eye (versus reaching beyond), and a longer snout (eye diameter 2.7-3.5 times in snout length versus 2.3-2.6, or eye diameter 27-35% snout length versus 23-26%).

**Morphology.** This is a small-sized and slender species with the body compressed

laterally. The body is deepest at the dorsal fin origin, and depth decreases towards the middle of the caudal peduncle. The caudal peduncle is 1.0-2.4 times longer than deep. The head is deep and narrow. The pelvic fin origin is below the vertical of the last unbranched to 1-3 branched dorsal fin rays. The caudal fin is moderately forked with rounded tips, the lower lobe usually larger and more rounded. The posterior dorsal and anal fin margins are straight or the dorsal fin is slightly concave. The tip of the anal fin, when pressed to body, does not reach or reaches to the middle of the caudal peduncle. The pectoral fin reaches approximately 50-65% of the distance from the pectoral fin origin to the pelvic fin origin. The pelvic fin does not reach back to the anus. The snout is 51-91% of the body depth at the dorsal fin origin. The gular region is rectangular. Lips are covered with papillae. The width of the upper lip is 4-6% of head length. The lower lip is thicker than the upper lip, with a well-developed median pad separated by a deep groove from adjacent gular tissue. The rostral barbel is short, not reaching the nostril. The maxillary barbel is 19-32% of head length, just reaching to the anterior half of the eye.

Dorsal fin unbranched rays 4 and branched rays 8, 65-80% of the posterior margin of the last unbranched dorsal fin ray covered with denticles, anal fin unbranched rays 3-4 (mode 4) and branched rays 5, pectoral fin branched rays 15-17 (mode 16), and pelvic fin branched rays 8-10 (mode 9). Lateral line scales 59-70, scale rows between the dorsal fin origin and the lateral line 12-15 (mode 12), scale rows between the pelvic fin origin and the lateral line 9-11 (mode 10), scale rows between the tip of the anal fin and the base of the caudal fin 5-9 (mode 6), predorsal scales 33-42 (mode 39), and scales around the caudal peduncle 26-29 (mode 28). A triangular axillary scale is present at the pelvic fin base. Total gill rakers number 8-11 (mode 8).

**Sexual dimorphism.** Unknown.

**Colour.** Live specimens are brown, brownish-grey to yellow, darker on the back, the flank is dark-brown, and the belly is yellowish to yellowish-white without spots. The dorsal, pectoral, anal and pelvic fins are brownish, and the caudal fin is yellowish. Numerous irregular dark-brown spots and medium-sized blotches are present on the back and flanks, and sometimes a few are present on the anal, pelvic and pectoral fins. The first barbel may have a few black spots, while the second barbel is yellowish without black spots. Preserved fish bear blotches and small spots on the head and flank, with a dark back and an immaculate belly and lower head surface. Blotching may be quite extensive and dense, or widely separated. The dorsal and caudal fins have dark pigment on fin rays without any evident pattern of bars. The anal and pelvic fins are almost immaculate and the pectoral fin has a few areas of pigment dorsally, proximally on the anterior fin rays.

**Size.** Reaches 15.4 cm (Khaefi *et al*., 2017) or 16.3 cm total length (Zare-Shahraki *et al*., 2020).

**Distribution.** This species is found in the Tigris River basin (upper Karun River basin) in Iran in the Beshar, Beheshtabad, Sangan, Semirom and Sheylaneh rivers (Ghorbani Chafi, 2000; Tabiee *et al*., 2014; Zamaniannejad *et al*., 2015; Khaefi *et al*., 2017; Pirali Khirabadi *et al*., 2017; Fatemi *et al*., 2019).

**Zoogeography.** See under *B. lacerta* and *B. miliaris*.

**Habitat.** This species is found in rivers and streams.

**Age and growth.** Zare-Shahraki *et al*. (2020) measured 145 fish, 4.0-16.3 cm total length, from the Karun River system and recorded a *b* value of 2.97.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

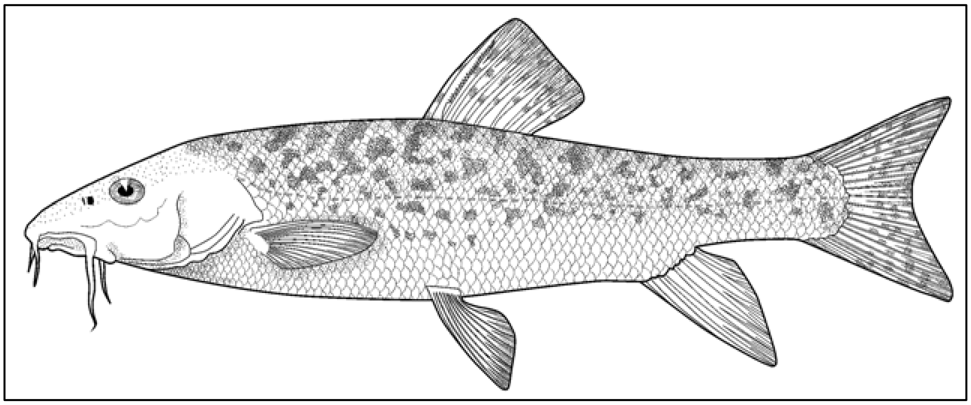
**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** This poorly known species requires study for conservation concerns. Jouladeh-Roudbar *et al*. (2020) considered it to be of Least Concern as there are many populations over its distribution range with no known threats.

**Sources.** Khaefi *et al*. (2017).

***Barbus lacerta***
Heckel, 1843



*Barbus lacerta*
Susan Laurie-Bourque @ Canadian Museum of Nature.

*Barbus lacerta*, 102.0 mm standard length, West Azarbayjan, Little Zab River,
Hamid Reza Esmaeili.

*Barbus lacerta*, Turkey, Göksu Glöbasi, Jörg Freyhof.

**Common names.** Blizem, bellizem, orenge (in reference to orange fins), sas or sos mahi (meaning of sas or sos unknown but referring to "*Barbus*"), sasmahi-ye khaldar (= spotted barb), zardehpar (in reference to yellow fins).

[Muraqqat (meaning spotted) and shabout moraqqat (from shabbut (meaning to beat or knock, and a large fish in the Tigris-Euphrates) (Mikaili and Shayegh, 2011)), in Arabic in Iraq; karad or karrid achmar (red frill or shag, probably from the colour and the long barbels) and karrid asrak (meaning blue shaggy one) according to Heckel (1843b) in Arabic in Aleppo; Bıyıklı balık in Turkish (Çiçek *et al*., 2020); lizard barbel (presumably after the colour pattern), Tigris barbel].

**Systematics.** Howes (1987) placed this species in his *Barbus sensu stricto*. Karaman (1971) assigned many taxa as subspecies of *Barbus plebejus* Bonaparte, 1832 (dated correctly 1839 in *Catalog of Fishes*, downloaded 30 May 2018, see Bianco (1995a) for details), found throughout Europe and Southwest Asia. Bianco (1995a) considered that *Barbus plebejus* is restricted to Adriatic drainages of Italy and Croatia. Valiallahi (2006) considered *B. plebejus* to be present in Iran and distinct from *B. lacerta* based mainly on body shape, the relative head length, the body depth and the fourth dorsal fin ray.

*Barbus plebejus kosswigi* Karaman, 1971 is described from the "Oberer Teil des Tigris-Systems" and "Hamam suyu, Beytusebab-Hakkari" (upper Tigris River basin in Turkey). Almaça (1991) considered it an ecophenotype of his *Barbus plebejus scincus* since two subspecies of the same species cannot live in the same river basin. *Barbus plebejus kosswigi* is a secondary homonym of *Cyclocheilichthys* (= *Carasobarbus*) *kosswigi* according to Kottelat (1997) and is a synonym of *B. lacerta* according to Kaya *et al*. (2016). *Barbus plebejus ercisianus* Karaman, 1971 is now recognised as a distinct species but was formerly placed as a synonym of *B. lacerta* (Khaefi *et al*., 2017). It was described from Ercis, Lake Van and road from Ercis to Patnos, Turkey with syntypes under ZMH H4208 and ZMH H3566 (5) and ZMH H3567 (13) (*Catalog of Fishes*, downloaded 7 February 2021).

Almaça (1981, 1983, 1984a, 1984b, 1986) gave *lacerta* specific status, distinguishing it from *Barbus plebejus* by the strong denticulations on the last dorsal fin unbranched ray, lower denticle density, number of scales in transverse rows, shorter head and pectoral fin, longer snout, lower body, the decrease in height of the dorsal fin branched rays gradual and the profile of the fin is straight, unusual in *Barbus* with a strongly denticulated dorsal spine. Almaça recognised two subspecies from Iranian drainages:- *lacerta* from the Tigris-Euphrates basin (and Aleppo) and *cyri* from the southern Caspian Sea basin. Berg (1948-1949) also referred Caspian Sea basin specimens to *Barbus lacerta cyri* but in Berg (1949) had *cyri* from the Tigris River basin too. Saadati (1977) suggested that Lake Urmia basin *Barbus lacerta* were a distinct

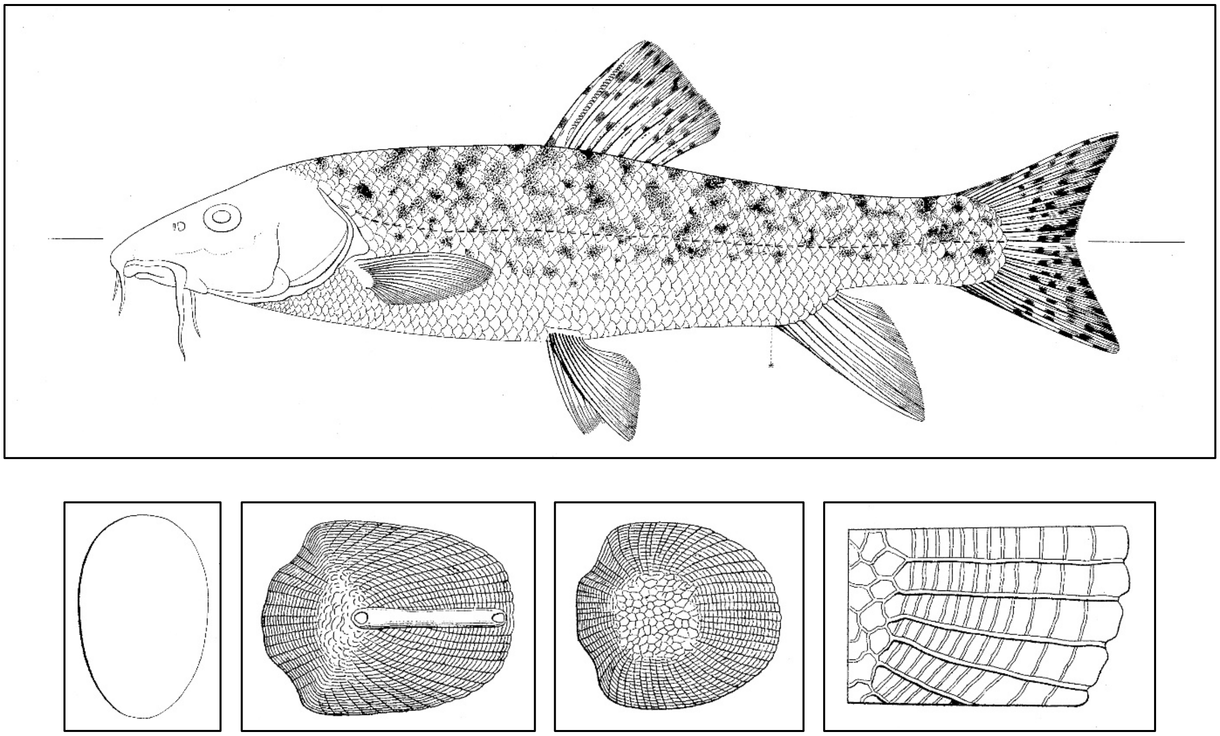
subspecies based on higher scale counts there (72-89) than in the Caspian Sea basin. However, *B. lacerta* as recognised has a wide range in scale counts (see below) and counting methods can differ to include or not supernumerary scales in the lateral line and small scales at the caudal fin base. Fishes resembling *B. lacerta* from the Namak Lake basin available to me were found to have some higher scale counts than Caspian Sea specimens although sample size was too small for a definitive study (but see *B. miliaris*). Berg (1948-1949) noted that his *B. lacerta cyri* was subject to extremely wide variations in such characters as body depth, fin and barbel lengths, dorsal spine denticle numbers (even absent in some very large fish) and lateral line scale counts, among others. A large series of specimens would have been needed to resolve these problems, allowing for size and sexual variation, new character discoveries, and consistent methodologies. Molecular studies would resolve this, and subsequently studies by Motamedi *et al*. (2011, 2014), Jalili *et al*. (2015) and Khaefi *et al*. (2017) revealed genetic, morphological and osteological differences between fish from the Caspian Sea, Lake Urmia and Tigris basins. See under *B. cyri* for a summary of osteological differences. Levin *et al*. (2019) recognised *B. lacerta* from the Tigris River basin as distinct from *B. cyri* of the Caspian Sea basin using mtDNA and nDNA.

The status of an Esfahan population remains unresolved and it too may be distinct (see **Sources** below).

*Barbus Lacerta* was described from the “Flüssen Kueik bei Aleppo” (Heckel, 1843b). Kaya *et al*. (2016) did not find this taxon in this river despite several attempts.

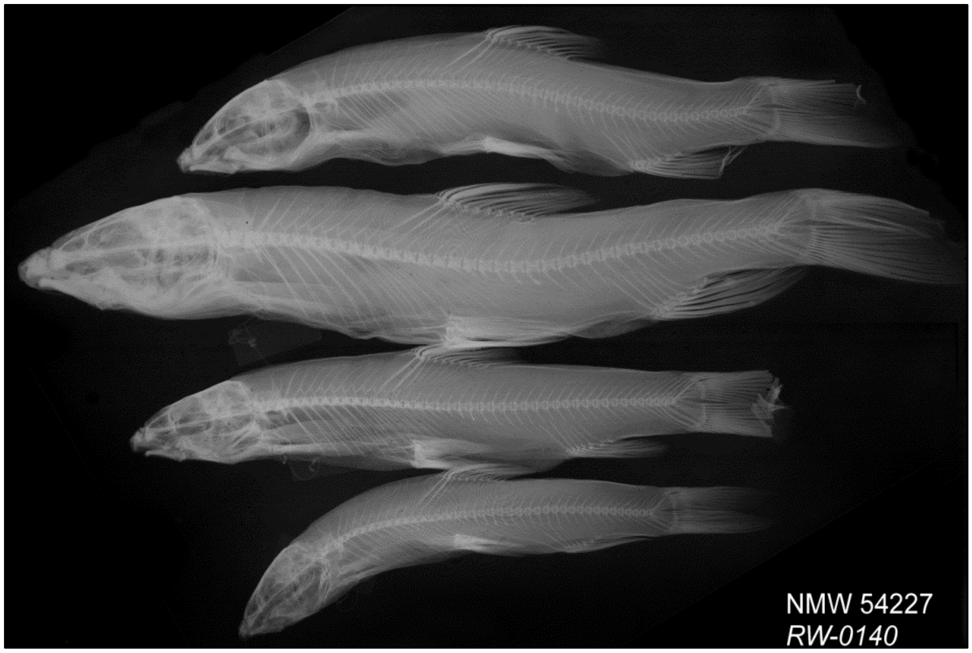
*Barbus Scincus* Heckel, 1843 described from “Aleppo” and later from the “Flusse Kueik bei Aleppo” in Heckel (1847a) is a synonym. Heckel (1843a) recognised *Barbus scincus* as close to his *Barbus lacerta* but with a shorter head, sharply decurved forehead, small mouth, and small eyes, all characters not easily quantified without detailed analysis. Berg (1949) placed it in the synonymy of *lacerta*. Berg’s view is followed here; others are described by Almaça (1983, 1984a, 1986) who favoured placing *scincus* as a subspecies of *Barbus plebejus* as noted above.

Four syntypes of *Barbus lacerta* are in the Naturhistorisches Museum Wien (NMW 54227, 108-182 mm standard length, which become a lectotype and paralectotypes after the Ichthyology Type Database, NMW (downloaded 9 July 2016), see below), one syntype is in the Senckenberg Museum Frankfurt (SMF 3471, formerly NMW), and one syntype is in the Museum für Naturkunde, Universität Humboldt, Berlin (ZMB 3236, formerly NMW, 110.3 mm standard length, examined February 2006; F. Krupp, pers. comm., 1985; Eschmeyer *et al*., 1996; Bogutskaya in Bănărescu and Bogutskaya, 2003). The Vienna card catalogue in 1997 listed one of NMW 54227 as the lectotype and Bogutskaya in Bănărescu and Bogutskaya (2003) designated 54227-1, 181.6 mm standard length, as the lectotype. The Vienna catalogue listed six specimens total. B. Riedel (pers. comm., 11 April 2019) also listed NMW 94655 as a syntype (dry bone, *sic*, probably a dried or stuffed specimen in this case).



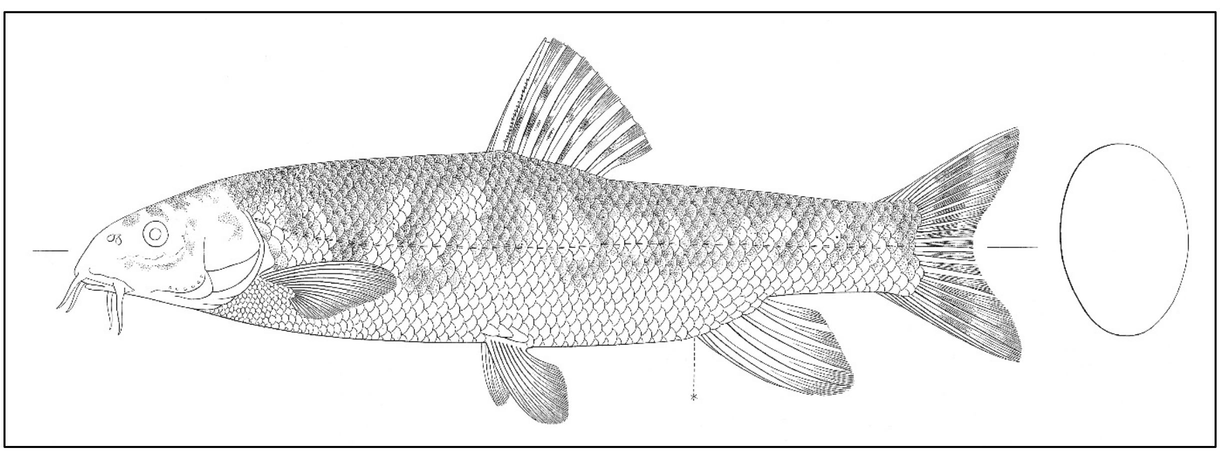
*Barbus lacerta*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

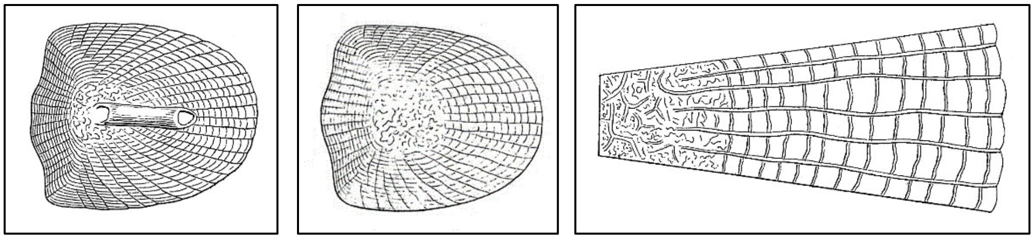

*Barbus lacerta*, lectotype and paralectotypes, NMW 54227,
Naturhistorisches Museum, Wien.




*Barbus lacerta*, lectotype and paralectotypes, NMW 54227,
Naturhistorisches Museum, Wien.

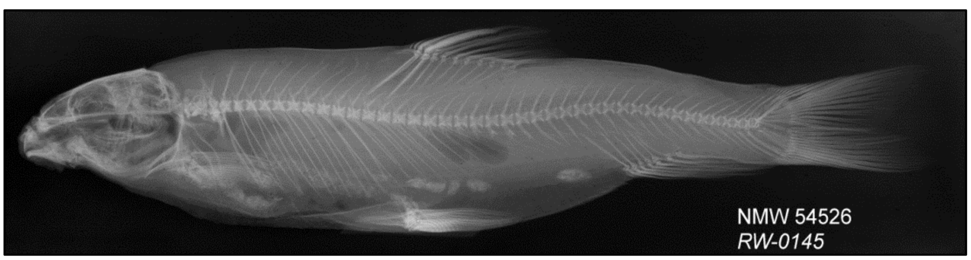
Syntypes of *Barbus scincus* from "Aleppo", the type locality in Heckel (1843b), are reported in the Naturhistorisches Museum Wien by Almaça (1986) and were also examined by me (NMW 22272, 2 specimens, 97.6-146.7 mm standard length, in poor condition and NMW 54526, 1 specimen, 158.8 mm standard length, designated as a lectotype by F. Krupp, 31 October 1984). Eschmeyer *et al*. (1996) and the Ichthyology Type Database, NMW (downloaded 9 July 2016) also listed NMW 54525 as a syntype and this fish measured 124.2 mm standard length and had been dried at some point before it was examined by me. The Vienna catalogue listed four specimens and the card catalogue in 1997 listed these four fish with NMW 54526 as "? lectotype" (*sic*).





*Barbus scincus*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Barbus scincus*, syntype, NMW 54526, Naturhistorisches Museum, Wien.




*Barbus scincus*, syntype, NMW 54526, Naturhistorisches Museum, Wien.

Tahmasebi *et al*. (2014c) examined fish morphometrically from the Lake Urmia, Tigris River and Caspian Sea basins. The results showed habitat-associated divergence, phenotypic plasticity and evolutionary body shape changes. The authors concluded that the populations are separate stocks in contrast to conclusions here that there are distinct species in two of these three basins.

**Key characters.** Khaefi *et al*. (2017) distinguished this species from other *Barbus* species in Iran by having an “almost” triangular gular region (versus rectangular) and a longer anal fin, reaching beyond the middle of the distance from the anal fin insertion to the lower caudal fin base (versus not reaching to the middle of the distance).

Khaefi *et al*. (2017) also distinguished *Barbus lacerta* from *B. cyri* by having a straight posterior anal fin margin (versus convex) and a narrow upper lip (its width 4-6% head length versus 7-9% head length). Other useful characters to identify *B. lacerta* from Khaefi *et al*. (2017) are a long snout, its length 46-56% of body depth at the dorsal fin origin, eye diameter 2.5-3.1 times in snout length, 52-66+2-4 total scales along the lateral line (but see below), 35-48 (mode 39) predorsal scales, 25-32 (mode 28) scales around the caudal peduncle, length of the caudal peduncle 1.7-2.0 times longer than depth, 60-70% of the posterior margin of the last

unbranched dorsal fin ray covered with denticles, and median pad at lower lip small.

**Morphology.** The head profile is convex and often depressed forward of the nostrils. The mouth is inferior and lips are thick to moderate. A median lobe on the lower lip is present in fish identified as *B. scincus* and absent in fish identified as *B. lacerta*. The barbels are thick, the anterior barbel reaching the nostril level and the posterior one the anterior to the posterior eye margin. The dorsal fin margin is rectilinear and oblique to the back. The last unbranched dorsal fin ray is weak with weak denticles over three-tenths to two-thirds of its length, with greater extent in larger fish, in fish identified as *B. scincus*, and dorsal ray moderate to strong and denticles over three-fifths to two-thirds in fish identified as *B. lacerta*. There may be up to 65 denticles and denticles may be absent in larger fish. Spines are larger proportionally in smaller fish seen by me and there is variation between individuals and populations. The tip of the last unbranched ray is thin and flexible. The depressed dorsal fin does not extend back to the anal fin origin level. The dorsal fin origin is over or slightly in front of the origin of the pelvic fin in *B. scincus* and over or slightly behind in fish identified as *B. lacerta*. The anal fin reaches, or does not reach, back to the procurrent caudal fin rays. Most of the above after Almaça (1986, 1991) based in part on 4 syntypes of *Barbus scincus*, NMW 22272, NMW 54523 and NMW 54526.

Dorsal fin with 3-5, usually 4-5, unbranched rays followed by 7-9, usually 8, branched rays, anal fin with 3 unbranched rays followed by 4-6, usually 5, branched rays, pectoral fin branched rays 13-19, and pelvic fin branched rays 6-10. Lateral line scales after Khaefi *et al*. (2017) are 52-67, and my count of 55-64 is for a small sample size of 11 fish. Literature counts, e.g., Geldiay and Balık (1996) and Coad (2010), include *B. cyri* which has a wide range in number of lateral line scales. The range in lateral line scale counts for this species is probably somewhat larger, particularly at the higher end. There are 0-3 (mode 2) scale rows between the tip of the anal fin and the base of the caudal fin (versus 3-6, mode 5, in *Barbus cyri*). There is a pelvic axillary scale. Scales are a horizontal oval to rounded to rectangular in shape with the anterior margin bearing a central protuberance, sometimes a wavy form, and rounded in young. Radii are numerous on all scale fields around a subcentral anterior focus with many circuli. Scales may be irregularly arranged on the flank because of their small size giving different counts depending on whether smaller scales are included in the lateral line count. In some fish, anterior flank scales are large and non-overlapping which also affects the scale count. Total gill rakers number 5-13, are short, and just reach the one adjacent when appressed. Rakers may not develop on the anterior arch giving a wide range in counts. Pharyngeal teeth are 2,3,5-5,3,2 with variants 2,3,5-5,3,1, 1,3,5-5,3,2, 1,3,5-5,3,1, 2,3,4-5,3,2, 2,3,5-4,4,2, 2,4,5-4,4,4 and even 1,2,3,5-5,3,2,1. The fourth inner row tooth is usually the largest, slightly larger, or slightly smaller in some, than the third. The fifth inner row tooth is blunt and other teeth are hooked or pointed. Teeth may be slightly serrated and there is a short concave surface below the hook. The gut is elongate with about two anterior loops and one posterior loop. Total vertebrae number 39-45. Nikmehr *et al*. (2016) recorded 40-42 vertebrae. The lectotype and paralectotypes, NMW 54227, of *B. lacerta* have 42(1), 43(2) or 44(1) and the paratype of *B. scincus*, NMW 54526, has 43.

Nikmehr *et al*. (2016) described the osteology of this species from the Hamill River, Ilam and compared it to that of *B. cyri*. *B. lacerta* has two pharyngobranchials (versus three), 7-8 supraneurals (versus 9), two long neural spines of the second centrum of the caudal skeleton (versus consumptive one), and lack of neural prezygapophyses of the fourth vertebrae (versus present).

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(11), anal fin branched rays 5(11), pectoral fin branched rays 14(1), 15(5), 16(3) or 17(2), pelvic fin branched rays 7(1) or 8(10), lateral line scales 55(1), 56(1), 57(-), 58(-), 59(3), 60(2), 61(1), 62(1), 63(1) or 64(1), total gill rakers 6(1), 7(-), 8(5), 9(1) or 10(3), pharyngeal teeth 2,3,5-5,3,2(4), and total vertebrae 42(3).

**Sexual dimorphism.** Fish may have fine tubercles over the whole body and fins, lining scale margins and scattered over the exposed scale surface on the anterior and upper flank, best developed behind the operculum and on neighbouring enlarged scales. Tubercles are also present on the cleithrum. Fine tubercles are also present on the head, and even variably on belly scales back to the pelvic fin. There are many fine tubercles on the pectoral, pelvic and anal fins, especially the pectoral fin, following the branching of the rays (based on CMNFI 1993-0126, 157.7 mm standard length, 11 May 1993). Generally, tuberculation appears to be quite variable and there is insufficient material to assess whether this is related to time of capture or size of fish (probably both).

**Colour.** The overall colour is yellowish to golden to olive-grey (possibly bluish according to Heckel (1847a)) or dark brown with numerous, regular dark-brown to black spots on the back, upper flank and dorsal and caudal fins and/or irregular mottling. Some fish are very blotchy with pigment down to the pelvic fin, while others are spottier and generally lighter. The spots may form a stripe in young fish. Spotting may be quite weakly developed. In general appearance, fish may be quite light or almost blackish as pigmentation level varies individually. The back is olive-brown to light or reddish-brown and the flanks silvery to yellowish. The belly and lower head surface are white. The iris is dark to silvery with a narrow silver-golden ring and some red. Barbels are white to red (presumably when infused with blood). The dorsal fin bears dark spots and extended lines of dark pigment on the rays and membranes, pigment extending from a half to the whole length of the fin rays. These are not clearly arranged as bars. The margin of the caudal fin is dark in some fish and there may be a band on mid-fin. The caudal fin is often speckled with dark spots which do not form clear bars. Extended lines of pigment may occur on the caudal fin rays, while in others much of the fin is dark. The pectoral fin has dark spots and there are odd dark spots on the pelvic and anal fins. Anal fin rays can be pigmented in mid-ray or be much lighter and less extensive. Both rays and membranes of the pectoral fin are pigmented with the rays darker. Pelvic fins can have as much as half the fin ray pigmented. Pectoral, pelvic and anal fins have reddish to orange tinges, best developed on the pectoral fin. All fins may be reddish. Generally, the pigment extent and pattern on fin rays is very variable. The peritoneum is a light brown with dense but spaced melanophores.

**Size.** Reaches 23.0 cm (Khalaf, 1961), and probably larger.

**Distribution.** This species is found in the Lake Van basin and adjacent Lake Nemrut in Turkey, the Euphrates, Tigris and Quwayq rivers in Turkey, Syria and Iraq, and the Esfahan, Hormuz, Lake Maharlu, Persis and Tigris River basins of Iran. In Iran it is found in the Esfahan basin in the Do Polan River; in the Hormuz basin in the Shur River; in the Lake Maharlu basin in the Khoshk River; in the Persis basin in the Mand, Qarah Aqaj, Rudbal (= Rudbar) and Tangab rivers; and in the Tigris River basin in the Alvand, Arvand, Avar, Bazoft, Beshar, Beheshtabad, Bibi-Sayyedan, Bid Sorkh, Dinorab, Dinvar, Gamasiab, Gaveh, Gholghol (= Gol Gol), Goleyn, Hamill, Haramabad, Harud, Kahman, Kakelestan, Kangavar Karkheh, Karun, Kashkan, Kalwi, Kelas, Kharchang, Khorram (Khorramabad), Kohneh, Leyleh, Little Zab, Marun, Marvil-Bighash, Mehr Gerd, Qareh Su, Qeshlaq, Qodarkabk,

Razavar (= Raz Avar), Roudbar, Sepidbarg (= Sefid Barg), Sirvan, Solgan and Zard rivers, the Gamasiab and Haramabad wetlands, sarabs in Kermanshah and the Qeshlaq Dam (Berg, 1949; Abbasi *et al*., 2009; Biokani *et al*., 2011; Bahrami Kamangar *et al*., 2012a; Biukani *et al*., 2013; Hasankhani *et al*., 2014; Reyahi-Khoram *et al*., 2014; Dopeikar *et al*., 2015; Dopeikar and Keivany, 2015a; Alizadeh Marzenaki *et al*., 2016; Nikmehr *et al*., 2016; Jamali Ashtiani *et al*., 2016; Jouladeh-Roudbar *et al*., 2016; Taghiyan *et al*., 2016; Azizi *et al*., 2017; Khaefi *et al*., 2017, 2017; Eagderi *et al*., 2019; Fatemi *et al*., 2019; Hasankhani *et al*., 2019).

**Zoogeography.** Almaça (1991) considered that this species arose from the first wave of colonisers to enter West Asia from South Europe but is more recent in origin than such *Barbus* (= *Luciobarbus*) species as *esocinus* and *xanthopterus* originating from southwestern Siberia. Levin *et al*. (2012) stated that this species diverged from *B. cyri* about 60,000 years ago. Motamedi *et al*. (2014), however, concluded that the species *B. cyri*, *B. lacerta* and his *B*. sp. Lake Urmia (now considered to be *B. cyri*) arose due to vicariance events 5-10 MYA. Khaefi *et al*. (2017), using DNA barcode data, found that *B. cyri* and *B. lacerta* are a young species pair with morphological similarities and little genetic differentiation. Khaefi *et al*. (2017) found this species to be the sister group to *B. karunensis* and *B. miliaris*, and noted the possibility of headwater stream capture between the Namak Lake and Tigris River basins (*miliaris* with *karunensis* and *lacerta*). Levin *et al*. (2019) placed this species in a Caspian lineage along with *B. cyri*, and with the Ciscaucasian sister species *B. ciscaucasicus* Kessler, 1877 and *B. kubanicus* Berg, 1912 (both the latter not in Iran). As part of a lineage of Ponto-Caspian barbels, these species diverged in the Pliocene, approximately 4.87 MYA, when the former Paratethys Sea was divided into several inland seas like the modern Black and Caspian seas. The Caspian lineage separated from the Balkanian one in the Middle Miocene, 16.23 MYA, during an Alpine orogeny accommodated by continuing collision of the Afro-Arabian plate with the Eurasian plate.

**Habitat.** This species is found in rivers, streams, lakes, dams, marshes and springs. Collection data included a temperature range of 20-30ºC, pH 6.5-6.8, river width 2-8 m or more, slow to medium current, capture depth 22-200 cm, clear, muddy or polluted water, detritus, mud, clay, sand, gravel or stone bottoms, submergent, emergent and floating vegetation, and a grassy shore.

Habitat of *Barbus lacerta*, Khuzestan, Zard River at Bagh-e Malek, 20 September 1995, Brian W. Coad.

**Age and growth.** Hasankhani *et al*. (2014) found a *b* value of 3.28 for 35 fish, 5.9-11.9 cm total length, from the Sirvan River. Nowferesti *et al*. (2014) found a *b* value of 3.22 for 36 fish, 2.9-12.9 cm total length, from the Sefid Barg and Dinvar rivers. A total of 389 fish, 5.7-23.3 cm total length, from the Bibi-Sayyedan River in the upper Tigris River basin near Semirom were examined by Dopeikar and Keivany (2015b) and Dopeikar *et al*. (2015). The oldest males were 4 years and females 7 years in, the male:female sex ratio was 1.5:1, body condition factor ranged from 1.77 to 2.17 (not significant between the same age groups but significant between months), growth rates were negative allometric (*b* was 2.9586 for females and 2.7566 for males), growth parameters were $L_t = 34.19[1\text{-}e^{-0.0943(t+2.2958)}]$ for females and $L_t = 23.85[1\text{-}e^{-0.1419(t+1.914)}]$ for males, the average specific growth rate (G) was 0.44 for females and 0.61 for males (faster for males), the Ǿ value (growth performance index) was 4.7 for females and 4.4 for males, the annual natural mortality rate was 0.55 for females and 0.48 for males based on length information and 0.61 for females and 0.5 for males based on weight information, and the species was slow-growing with a relatively high mortality rate. Keivany *et al*. (2016) gave a *b* value for 446 fish, 2.6-23.23 cm total length, from the Bibi-Sayyedan River of 2.8509.

Dartay and Gül (2014) found a length-weight relationship for 27 Keban Dam, Turkey fish, 30.4-47.4 cm total length, of $W = 0.0124L^{2.938}$. Serdar and Özcan (2018) examined 162 fish from 14 stations in the Qarasu River in eastern Anatolia, Turkey and found a *b* value of 3.1

(isometric growth) and a condition factor of 1.176.

**Food.** Plant remains, crustaceans such as amphipods and insect remains such as chironomids and dragonfly larvae have been found in gut contents examined by me. Dopeikar and Keivany (2015a) examined fish from the Bibi-Sayyedan River and concluded this fish was in the relative gluttonous group with an omnivory habit biased towards carnivory, mostly feeding on aquatic insects, and with a continuous feeding strategy throughout the year.

**Reproduction.** Small Iranian specimens (130.7-157.7 mm standard length, CMNFI 1993-0128 and 1993-0126) examined by me have eggs of 1.0 mm diameter and 1.1 mm (both capture dates 11 May 1993). The spawning season is probably spring for large fish as they had well-developed tubercles.

Dopeikar *et al*. (2011, 2015) found fish from the Bibi-Sayyedan River had a male:female sex ratio of 1.8:1, females are generally larger than males, became sexually mature in the first year of life, the gonadosomatic index was highest in April for both sexes when spawning peaked although intermittent spawning took place from late March to August when temperatures reached 17.2-19.9°C (or 17.2-20.4°C in the earlier reference), egg diameter reached 2.25 mm in April, mean absolute fecundity was 8,249 eggs, and relative fecundity was 140 eggs/g. This study also examined gonad histology.

**Parasites and predators.** Unknown.

**Economic importance.** It is used locally as food in Iran (Dopeikar *et al*., 2015).

**Experimental studies.** None.

**Conservation.** This species has not been assessed in Iran and fewer collections were made using similar techniques than for *B. cyri*. Endangered in Turkey, the status including *B. cyri* (Fricke *et al*., 2007). Listed as of Least Concern by the IUCN (2015) and Jouladeh-Roudbar *et al*. (2020).

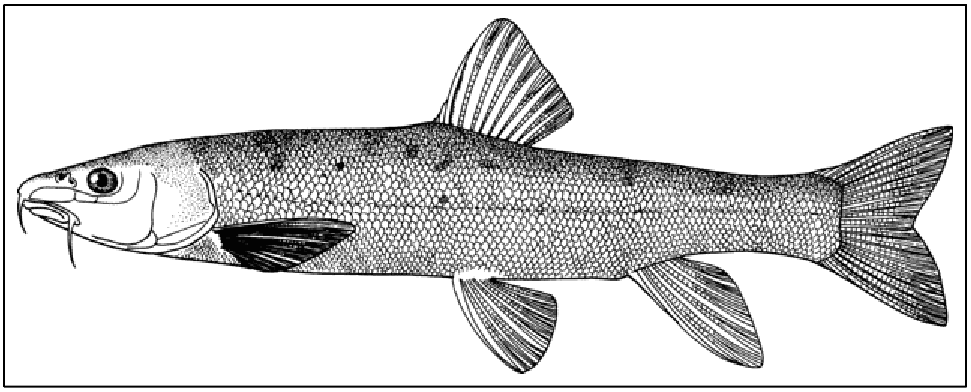
**Sources.** Type material:- *Barbus lacerta* (NMW 54227, SMF 3471 and ZMB 3236) and *Barbus scincus* (NMW 22272, NMW 54525 and NMW 54526).

Iranian material:- CMNFI 1979-0271, 2, 42.1-44.7 mm standard length, Lorestan, river in Kashkan River drainage (33º39'N, 48º32'30"E); CMNFI 1979-0289, 1, 131.6 mm standard length, Kermanshah, river in Diyala River drainage (34º28'N, 45º52'E); CMNFI 1993-0125, 1, 83.1 mm standard length, Kermanshah, Sarab-e Nilufar (34º24'N, 46º52'E); CMNFI 1993-0126, 1, 157.7 mm standard length, Kermanshah, Sarab-e Yavari (34º28'N, 46º56'E); CMNFI 1993-0128, 1, 130.7 mm standard length, Kermanshah, Sarab-e Sabz ‘Ali Khan (34º25'N, 46º32'E); CMNFI 2007-0099, 2, 28.9-132.1 mm standard length, West Azarbayjan, Kalwi Chay west of Mahabad (ca. 36º35'N, ca. 45º25'E); CMNFI 2007-0100, 1, 42.3 mm standard length, West Azarbayjan, Kalwi Chay near Piranshahr (ca. 36º44'N, ca. 45º10'E); CMNFI 2007-0117, 1, 66.4 mm standard length, Kermanshah, Gamasiab River near Sahneh (ca. 34º24'N, ca. 47º40'E); CMNFI 2007-0118B, 1, 51.3 mm standard length, Kermanshah, Bid Sorkh River between Sangeh and Kangavar (ca. 34º23'N, ca. 47º52'E); CMNFI 2008-0151, 1, 140.3 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); CMNFI 2008-0175, not kept, Lorestan, Kahman River at Dow Ab-e Aleshtar (33º47'N, 48º12'E); CMNFI 2008-0188, 1, 56.4 mm standard length, Esfahan, Mehr Gerd River (31º34'N, 51º32'E).

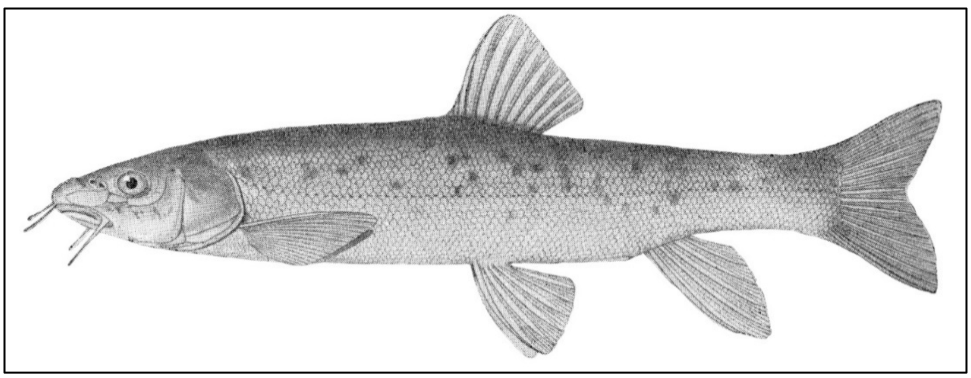
Comparative material:- BM(NH) 1974.2.22:1236, 1, 113.8 mm standard length, Iraq, Karrid chmar (no other locality data); BM(NH) 1974.2.22:1327-1328, 2, 121.0-129.9 mm standard length, Iraq (no other locality data); BM(NH) 1974.2.22:1349-1350, 2, 63.1-83.0 mm standard length, Iraq, Qizillja River, Lesser Zab and Serokani near Diana, Rowanduz, Greater

Zab (mixed sample); BM(NH) 1974.2.22:1351, 1, 146.8 mm standard length, Iraq, Karrid Asrak (no other locality data).

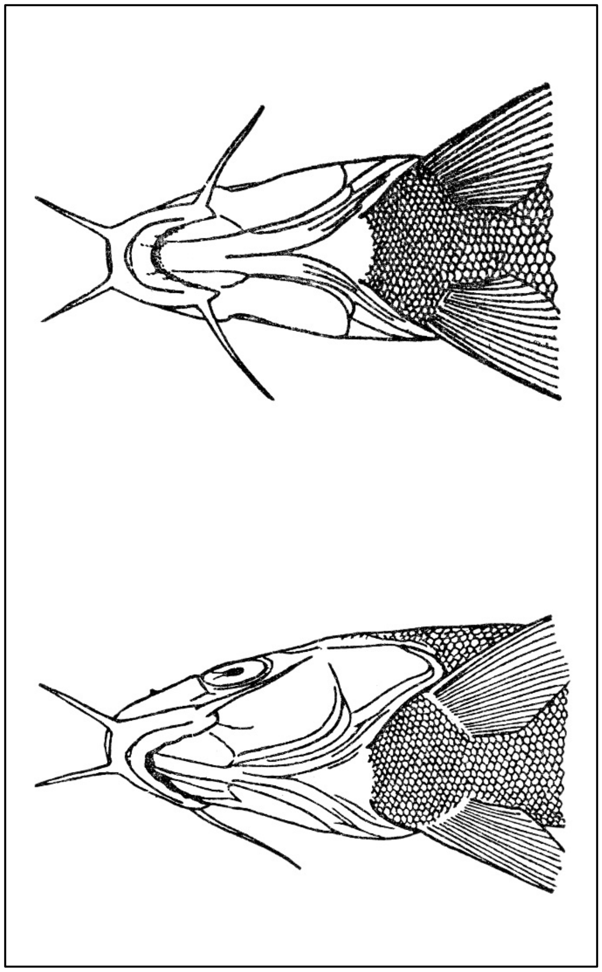
### ***Barbus miliaris***
De Filippi, 1863



*Barbus miliaris*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Barbus miliaris*, 21.0 cm total length, Tehran, after Berg (1949).



*Barbus miliaris*, as above, head views,
after Berg (1949).

*Barbus miliaris*, 65.0 mm standard length, Qom, Qom River, Hamid Reza Esmaeili.

*Barbus miliaris*, 71.0 mm standard length, Semnan, Hableh River, Hamid Reza Esmaeili.

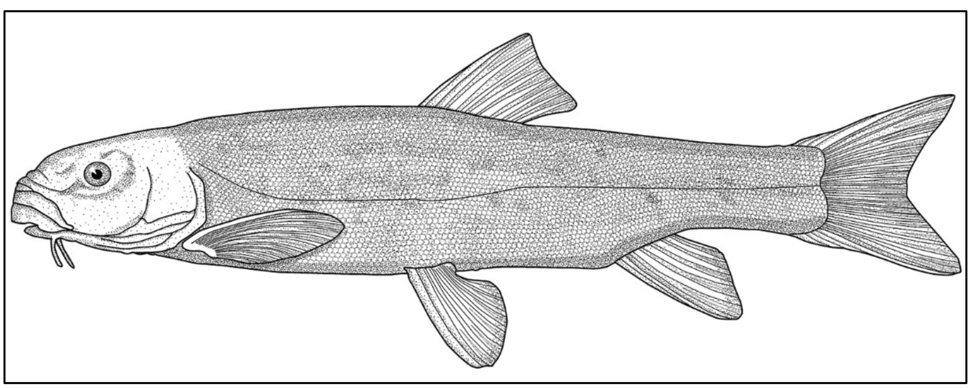
**Common names.** Sas or sos mahi Namak, orenj-e Namak (from orange fin colour and locality).

[Namak barbel].

**Systematics.** *Barbus miliaris* De Filippi, 1863 was described from a "fiumicelli presso Teheran" (= a stream near Tehran). Three specimens (presumably syntypes) (MZUT N.676) of *Barbus miliaris* are stored in the Istituto e Museo di Zoologia della R. Università di Torino (Tortonese, 1940).

*Barbus miliaris*, syntype, MZUT N.676, 100.0 mm standard length, Hamid Reza Esmaeili.

*Barbus kessleri* Derzhavin, 1929 described in Latin from the "Keredsh flumen" (= Karaj River near Tehran) (types unknown), and *Barbus dageti* Fowler, 1958, are synonyms. *Barbus dageti* was coined because Fowler believed *Barbus kessleri* was preoccupied by *Puntius kessleri* Steindachner, 1866 from Angola; *Puntius* Hamilton, 1822 is not now considered a synonym of *Barbus sensu lato* (Eschmeyer, 1990) although Eschmeyer *et al*. (1996) had *Barbus kessleri* listed as preoccupied by *Puntius kessleri*. Eschmeyer *et al*. (1996) recorded three syntypes "whereabouts unknown" for *Barbus dageti*, i.e., Derzhavin's *Barbus kessleri* types. *Barbus kessleri* was listed as a synonym of *Luciobarbus mursa* in the *Catalog of Fishes* (downloaded 30 May 2018) as *B. miliaris* too was considered a synonym of that species.



*Barbus kessleri*, after Derzhavin (1929),
re-drawn by Susan Laurie-Bourque @ Canadian Museum of Nature.

Howes (1987) considered the generic placement of *Barbus miliaris* as problematical. It has a series of preanal scales and a prominent genital papilla similar to schizothoracines, and a lachrymal bone similar to *Barbus* (= *Arabibarbus*) *grypus* and *Mesopotamichthys sharpeyi*. Karaman (1971) considered *Barbus miliaris* from the Namak Lake basin of Iran to be a subspecies of the Caspian Sea basin *Barbus* (= *Luciobarbus*) *mursa*, differentiated by larger scales (78-92 compared to 85-103), less fleshy lips, an undeveloped lower lip lobe, feebly ossified last dorsal fin spine, and shorter pectoral fins. Derzhavin (1929b), in describing his

*Barbus kessleri* on fish 121-154 mm total length with well-developed gonads, stated that the lower lip is clearly trilobate. Berg (1949) recognised *miliaris* as distinct from *L. mursa* on the basis of a shorter snout, somewhat larger scales, fewer scale rows above the lateral line, smaller dimensions, and different colour. Bianco and Banarescu (1982) and Almaça (1984b) retained it as a full species although Bianco and Banarescu (1982) also suggested that this species may be a subspecies of their wide-ranging taxon *Barbus cyclolepis* Heckel, 1837. Almaça (1984a) pointed out that his conclusion was based in part on small specimens in poor condition and that there was not enough data to take a sound decision (Almaça noted that gill raker counts were low and the lower lip lobe undeveloped in accordance with Karaman (1971) but these are characters which I believe may be size and age related). Almaça (1992) also distinguished the two taxa on the shorter barbel in *miliaris* (not exceeding the middle of the eye as opposed to not exceeding the rear border of the eye), slope of the dorsal fin oblique in *miliaris* as opposed to oblique to nearly perpendicular, and pharyngeal teeth in *miliaris* 5,3 (or 4),2 as opposed to 4-5,3,2. These characters too may be size dependent or individually variable, as are those of Berg (1949).

Jouladeh-Roudbar *et al*. (2015), Valiallahi (2015) and Khaefi *et al*. (2017) recognised this species as distinct from *Barbus mursa* (now *Luciobarbus mursa*) based on such characters as a shorter snout, less fleshy lips, an undeveloped lower lip lobe, somewhat larger scales, fewer scale rows above the lateral line, smaller dimensions, and different colour.

**Key characters.** Khaefi *et al*. (2017) distinguished this species from other *Barbus* species in Iran by having 69-87, mode 77 (but see above and below for wider counts), lateral line scales (versus 50-66 with modes of 57 in *B. cyri* and 61 in *B. lacerta*) and 80-95% of the last dorsal fin unbranched ray with denticles (versus 60-70%). Distribution is also key.

Other characters are more predorsal scales (37-47 (mode 42) versus 24-34 (mode 29) in *B. cyri*), a narrower upper lip (4-6 versus 7-9% head length), and a longer maxillary barbel (26-41 versus 12-32% head length) in *B. lacerta*, not reaching to posterior eye margin (versus reaching in *B. lacerta*). *Barbus miliaris* is also distinguished from *B. cyri* by having a straight posterior anal fin margin (versus convex) and from *B. lacerta* by the tip of the anal fin, when pressed to the body, reaching to about the middle of the distance between the base of the last anal fin ray and the lower caudal fin origin (versus beyond, often to caudal fin base). *Barbus miliaris* also has 3-6 (mode 4) scale rows between the tip of the anal fin and the base of the caudal fin (versus 0-3), and a rectangular gular region (versus triangular). Other useful characters to identify *B. miliaris* are snout length 54-57% of body depth at dorsal fin origin, eye diameter 2.3-2.6 times in snout length, length of caudal peduncle 1.7-2.2 times longer than deep, and median pad of lower lip shallow.

**Morphology.** The body is small-sized and slender, compressed laterally. The dorsal profile is almost arched and the ventral profile almost straight. The predorsal profile is convex. The head profile is convex and the head is deep and narrow. The head profile is slightly depressed with a groove in front of the nostrils. The body is deepest at the dorsal fin origin. The mouth is inferior with thick lips and a variably developed median lobe on the lower lip. Lips are covered with papillae. The barbels are thick with the anterior one reaching the anterior nostril level and the posterior one the middle of the eye. The anterior barbels hang over the lip. The dorsal fin margin is slightly concave and oblique to the back. The last unbranched ray and its denticles are strong to moderate. Denticles extend up to 69% of the ray length in Almaça (1984a) or 80-95% in Khaefi *et al*. (2017), evidently variable. The depressed dorsal fin extends back to or nearly to the level of the anal fin origin. The dorsal fin origin is slightly behind the

pelvic fin origin. The anal fin tip does not reach back to the procurrent caudal fin rays. The pectoral fin does not reach back to the pelvic fin and the pelvic fin does not reach back to the anal fin. The caudal fin is moderately forked with rounded tips.

Dorsal fin with 4 unbranched rays and 7-8, mode 8, branched rays, anal fin with 4 unbranched rays and 5 branched rays, pectoral fin branched rays 14-17, mode 16, and pelvic fin branched rays 8-10, mode 9. Lateral line scales 69-90, mode 82 (mode from Khaefi *et al*. (2017), illustrating generally a high scale count). Scales around caudal peduncle 28-35, mode 32. A triangular pelvic axillary scale is present. Scales are a horizontal oval to rectangular in shape with the anterior margin bearing a central protuberance, and sometimes a wavy form, rounded in young. Young fish have rounded scales. Radii are numerous on all scale fields around a subcentral anterior focus with many circuli. Total gill rakers number 9-12, mode 10, touching the raker below when appressed, and gill rakers are minute so counts could be size related. Pharyngeal teeth are 2,3,5-5,3,2 with occasionally only one tooth in the outer row. Main row teeth are hooked at the tip and scalloped below. The gut is an elongate s-shape with two anterior loops and one posterior loop. Total vertebrae number 41-43.

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(9), anal fin branched rays 5(8), pectoral fin branched rays 14(1), 15(3) or 16(5), pelvic fin branched rays 8(8), lateral line scales 75(1), 76(1), 77(1), 78(1), 79(1), 82(1), 84(2) or 89(1), and total gill rakers 9(4), 10(3), 11(1) or 12(1).

**Sexual dimorphism.** None observed (Khaefi *et al*., 2017). Etessami (1982) reported a hermaphrodite in this species in the Namak Lake basin.

**Colour.** Live fish are dark brown to a light grey, darkest on the back and upper flank and lighter on the lower flank. The pectoral, and to a lesser extent the pelvic fins, have orange tinges while the anal fin has little pigment. Preserved material is an overall light to dark brown with irregular darker patches and speckles of varying size scattered over the body, particularly on the anterior flank, and with small dark spots scattered on the head, body, and dorsal and caudal fins. Occasional fish have few patches and spots. The lower flank and belly are lighter than the upper flank but even the belly can be well-pigmented. The anal and pelvic fins are mostly immaculate with only occasional patches of pigment on the rays in some fish.

**Size.** Attains 21.0 cm total length (Berg, 1949).

**Distribution.** This species is found in the Dasht-e Kavir and Namak Lake basins in Iran. In the Dasht-e Kavir basin recorded from the Hableh and Nam rivers; and in the Namak Lake basin in the Fordoghan, Karaj, Ken, Mazdaghan, Qareh Chay and Qom rivers, the Saveh Dam and probably the Al-Ghadir Dam on the Qareh Chay (Berg, 1949; Wossughi, 1978; Bianco and Banarescu, 1982; Etessami, 1982; Almaça, 1984a; Abbasi *et al*., 1999; Abdoli, 2000; Touraji and Vosoughi, 2006; Jouladeh-Roudbar *et al*., 2015; Khaefi *et al*., 2017, 2017; Eagderi *et al*., 2019).

**Zoogeography.** This taxon is related to the Caspian Sea species (*B. cyri*) rather than the Tigris River species (*B. lacerta*) according to Motamedi *et al*. (2014). Khaefi *et al*. (2017) suggested headwater stream capture between the Namak Lake and Tigris River basins accounted for the observed distinct mitochondrial lineage between *B. miliaris* and *B. karunensis*.

**Habitat.** This species is found in rivers, streams, dams and qanats. The Qom River sampling site of Khaefi *et al*. (2017) was 2-3 m wide with a substrate of coarse gravel and boulders, moderate riparian vegetation, and almost slow-flowing and transparent water. The physicochemical parameters were dissolved oxygen 8.44 mg/l, total dissolved solids 2.67 g/l,

salinity 2.72‰, conductivity 5.08 ms/cm, pH 8.19, and water temperature 30.15°C. At the Hableh River sampling site the river was about 5-10 m wide with a substrate consisting of coarse gravel and boulders, poor riparian vegetation, and almost fast-flowing and transparent waters. The physicochemical parameters were dissolved oxygen 7.96 mg/l, total dissolved solids 2.27 g/l, salinity 2.06‰, conductivity 3.91 ms/cm, pH 8.32, and water temperature 21.8°C. Collection data included a temperature range of 21-26ºC, pH 6.0-6.5, conductivity 1.85-3.7 mS, river width 7-12 m, slow to fast current, capture depth up to 1.0 m, clear or cloudy water, mud, sand or pebble bottoms, encrusting vegetation, and a grassy shore.

Habitat of *Barbus miliaris* (and *Capoeta buhsei*), Qom, Qom River, Hamid Reza Esmaeili.

**Age and growth.** Unknown.

**Food.** Unknown, but presumably similar to other *Barbus* species.

**Reproduction.** Unknown.

**Parasites and predators.** *Lernaea* parasites were found damaging fins in CMNFI 1979-0253.

**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** Khaefi *et al*. (2017) considered it extirpated from the Karaj River in the Namak Lake basin, the probable site of the original description. Jouladeh-Roudbar et al. (22020) listed it as Near Threatened because of significant declines in the Dasht-e Kavir and Namak Lake basins although an ability to live in reservoirs and other artificial water bodies had a buffering effect.

**Sources.** Iranian material:- CMNFI 1979-0253, 4, 48.6-60.4 mm standard length, Qom, river in Qareh Chay drainage (34º52'N, 50º49'E); CMNFI 1979-0462, 1, 37.6 mm standard length, Markazi, Mazdaqan River (35º06'30"N, 49º40'30"E); CMNFI 1979-0465, 1, 49.5 mm standard length, Markazi, Qom River (34º18'30"N, 50º32'E); CMNFI 2008-0152, 1, 118.7 mm standard length, Namak Lake basin (no other locality data); FMNH 51245, 2, 108.4-128.5 mm standard length, Tehran, Rayy (35º35'N, 51º25'E); ZMH 2429, 1, 98.1 mm standard length, Tehran, Tehran (no other locality data).

***Barbus urmianus***
Eagderi, Nikmehr, Çiçek, Esmaeili, Vatandoust and Mousavi-Sabet, 2019

*Barbus urmianus*, paratype, 130.1 mm standard length, Hamid Reza Esmaeili.

**Common names.** None.

[Urmia barbel].

**Systematics.** The holotype of *Barbus urmianus* is under IMNRF-UT (Ichthyological Museum of Natural Resources Faculty, University of Tehran) 1079-8, 117.7 mm standard length, Western Azerbaijan prov., Mahabad-Chai River at Miriseh Village, Beytas City, 36°29'55.14"N, 45°33'54.26"E with paratypes under IMNRF-UT 1079-1-15, 14, 101.1-187.6 mm standard length, same data as holotype and VMFC B1388 (Vatandoust and Mousavi-Sabet Fish Collection, Tehran), 30, 95.0-184.2 mm standard length, same data as holotype. Jouladeh-Roudbar *et al*. (2020) placed this species in synonymy with *B. cyri* but gave no reasons and later Jouladeh-Roudbar (2021) stated that *B. cyri* is a synonym of this species (presumably the reverse was meant unless my translation was at fault) based on the COI gene. While this may be a valid assessment, the species is retained here as distinct because of reservations on the use of a single gene to synyonymise species, and the original authors may rebut the synonymy.

*Barbus urmianus*, holotype, IMNRF-UT-1079-8, Hamid Reza Esmaeili.


*Barbus urmianus*, paratypes, IMNRF-UT-1079-3, 5, 11, a. 124.0 mm standard length, b. 138.2 mm standard length, c. 113.4 mm standard length, Hamid Reza Esmaeili.

**Key characters.** This species is distinguished from other members of the *B. lacerta* group according to Eagderi *et al*. (2019) by a well-developed middle pad of the lower lip, a shorter postdorsal length (25.2-42.0 versus 46.4-60.7% standard length), a long anal fin (11.0-23.0 versus 6.0-10.4% standard length), a short dorsal fin base (9.2-15.6 versus 16.1-22.6% standard length), fewer scales around the caudal peduncle (14-23 versus 25-35), and 64-85 (mean 79.6) scales on the lateral line (versus 52-70). Distribution is also key.

*Barbus urmianus*, ventral head, Hamid Reza Esmaeili.

It is separated from *B. cyri*, also found in the Lake Urmia basin, by *B. cyri* having a postdorsal length 47.8-60.7% standard length (versus 25.2-42.0%), dorsal fin base 16.1-21.2% standard length, anal fin base 6.1-10.4% standard length, scales around caudal peduncle 28-33, scales in lateral line 52-69 (mean 59.4), and scales below lateral line 9-13 (versus 12-15).

**Morphology.** The body is elongate and cylindrical, with the greatest body depth somewhat before the dorsal fin origin decreasing towards the middle of the caudal peduncle, the predorsal body profile is convex, and the ventral profile is slightly convex. The head is moderately long and deep, tapering towards a rounded, blunt snout. The eye is small and the rear margin is at the beginning of the anterior half of the head. The dorsal profile of the head is slightly convex, with no marked hump between the head and body. The caudal peduncle is 1.7-2.9 times longer than deep. There is a triangular and pointed axillary scale at the pelvic fin base. The pelvic fin origin is below the vertical from the last unbranched dorsal fin ray. The caudal fin is shallowly forked with rounded tips. The posterior dorsal and anal fin margins are straight or slightly concave. The tip of the anal fin, when pressed to body, passes the middle of the caudal peduncle and almost reaches the procurrent caudal fin rays. The pectoral fin reaches approximately 55-75% of the distance from the pectoral fin origin to the pelvic fin origin. The pelvic fin does not reach back to the anus. The pelvic and pectoral fin margins are rounded. The snout length is 48-72% of the body depth at the dorsal fin origin. The width of the upper lip is 4.5-7.5% head length. The lower lip is thicker than the upper lip, with a well-developed median pad. The rostral barbel is short, not reaching back to the nostril and the maxillary barbel is 27-45% head length, reaching back beyond the middle of the eye.

Dorsal fin with 2-4 (mode 3) unbranched rays and 7-10 branched rays, 50-65% of the posterior margin of the last unbranched dorsal fin ray covered with denticles, anal fin with 2-3 (mode 2) unbranched and 5-7 branched rays, pectoral fin with 12-16 (mode 15) rays, and pelvic fin with 6-10 (mode 9) rays. Lateral line scales 64-85 (mean 79.6). Scale rows between the dorsal fin origin and the lateral line 15-18 (mode 16), scale rows between the pelvic fin origin and the lateral line 12-15 (mode 12), scales around the caudal peduncle 14-23 (mode 21), and predorsal scales 25-31 (mode 28). Total gill rakers number 6-9 (mode 7). Pharyngeal teeth are 1,4-4,1.

**Sexual dimorphism.** Unknown.

**Colour.** Live specimens have the body and head yellow to brown, flanks are brown, lighter below the lateral line, the belly is yellowish white, there are numerous small, irregular dark-brown spots and small blotches on the back and flanks, and there are a lower number of irregular dark-brown spots on the fins. The dorsal and caudal fins are more heavily spotted than the lower fins. The dorsal, pectoral and pelvic fins are brownish with a faded orange colour anteriorly. The caudal and anal fins are brownish. The lateral line is visible as a thin light line. The barbels are yellowish. Preserved specimens have the body and head brown with the flanks darker above the lateral line, the belly is light brown without spots, and there are dark brown irregular spots and small blotches scattered on the entire body. Fins are cream to yellowish. Barbels are light brown.

**Size.** Attains 187.6 mm standard length.

**Distribution.** This species is found in the Mahabad River of the Lake Urmia basin

. **Zoogeography.** Presumably a close relative of *B. cyri* and derived from the Caspian Sea basin where that species is also found as well as in Lake Urmia.

**Habitat.** The habitat photograph in Eagderi *et al*. (2019) showed a shallow and narrow stream with a gravel and pebble bed and some bank vegetation.

Type locality of *Barbus urmianus*, West Azarbayjan, Mahabad River at Miriseh Village, Hamid Reza Esmaeili.

**Age and growth.** Unknown.
**Food.** Unknown, but presumably similar to other *Barbus* species.
**Reproduction.** Unknown.
**Parasites and predators.** None.
**Economic importance.** None.
**Experimental studies.** None.
**Conservation.** Recorded only from a single river known to have pesticide influx (Honarpajouh, 2003) as well as other wastes and likely to be under some threat.
**Sources.** Based on Eagderi *et al*. (2019).

## Genus *Capoeta*
Valenciennes, 1842

The genus *Capoeta* has a wide distribution in Southwest Asia and contains about 37 species of which about 18 occur in Iran (Ghanavi *et al*., 2016; Elp *et al*., 2018).

*Varicorhinus* Rüppell, 1835 (as used for Southwest Asian cyprinids) is a synonym of *Capoeta* Valenciennes, 1842 (see Karaman (1969a) for further details: *Capoeta* is distinguished from *Varicorhinus* of Africa (now *Labeobarbus* Rüppell, 1835) since it has a denticulate last dorsal fin unbranched ray (as opposed to smooth), very small to medium-sized scales (large), lachrymal bone narrow and covering only a small part of the upper side of the rostrum (large and covering most of the rostrum), suborbital bones narrow and long (short and wide), posterior maxillary process not extending back to a level with the centre of the jugal (extends back to a level of the centre of the suborbitals), and lower jaw long (short). The genus *Capoeta* is also characterised by an elongate, cylindrical body, a short dorsal fin with (3)4-5(6) unbranched and 7-9(10)(11) dorsal fin branched rays, 3 unbranched and 5 anal fin branched rays, a ventral mouth with a horny sheath on the lower lip, one pair of barbels (rarely two), and pharyngeal teeth in three rows, 2,3,4-4,3,2 or 2,3,5-5,3,2. Ayvazyan *et al*. (2019a) described the three-dimensional morphology of the pharyngeal dentition on 10 species, six of which are

found in Iran, and found agreement with molecular studies, specific identification, use in the fossil record, and possible trophic segregation.

*Scaphiodon* Heckel, 1843 has been used for *Capoeta* and *Cyprinion* species in Southwest Asia. The nomenclatural status of this genus is reviewed by Bănărescu in Bănărescu (1999) and it is a synonym of *Capoeta*. Zareian *et al*. (2018) referred to a "*Capoeta xazari*" from the Kavir basin in their Table 3 and this is presumably an error for what was later realised to be *C. aculeata*.

Levin *et al*. (2012) using cytochrome *b* found that *Capoeta* is a monophyletic clade nested within *Luciobarbus,* with origins in the Middle Miocene of a palaeo-Tigris-Euphrates basin. The genus originated about 13.9 MYA and diversified in the Middle Miocene-Late Pliocene period. *Luciobarbus subquincunciatus* is the closest relative and is only found in the modern Tigris-Euphrates basin. The specialised algae scraping morphology appeared once within the evolution of *Capoeta*. Three main groups were detected, the Mesopotamian group (*anamisensis*, *barroisi* (as formerly recognised, now *mandica*) and *trutta* in Iran), the Anatolian-Iranian group (*buhsei*, *coadi*, *damascina*, *saadii*), and the Aralo-Caspian group (*aculeata*, *alborzensis* (= *aculeata*), *capoeta*, *fusca*, *heratensis*), with information from Jouladeh-Roudbar *et al*. (2016, 2017) and Bektas *et al*. (2019). The origin of the genus was most probably through allopolyploidisation, as species are hexaploids (2n = 150). Yang *et al*. (2015) suggested the hexaploidisation event may be due to an ancient hybridisation between a *Luciobarbus* species (maternal source) and a *Cyprinion* (paternal source). The separation of the Mesopotamian clade occurred in the Middle Miocene about 12.6 MYA, of the Iranian members of the Anatolian-Iranian group in the Pliocene soon after 6.7 MYA, and of the Aralo-Caspian group during the later Pliocene 2.6 MYA (Levin *et al*., 2012). Hashemzadeh Segherloo *et al*. (2014) barcoded *Capoeta aculeata*, *C. buhsei*, *C. damascina* and *C. trutta*, determined the genus to be monophyletic with greatest divergence between *aculeata* and *trutta* and the least between *buhsei* and *damascina*. The oldest divergence time was at 9.6-14.38 MYA and the latest at 3.55-5.19 MYA. Babaei *et al*. (2017) also found *Capoeta* to be a monophyletic group with close affinity to *Luciobarbus*, using the COI gene.

Preliminary studies of the Iranian species by Razavi Pour *et al*. (2013) using morphometry and Zareian and Esmaeili (2013) using morphometry, meristics and DNA data indicated some relationships and two major clades. Zareian *et al*. (2016) and Zareian and Esmaeili (2017) used cytochrome *b* and COI sequences to determine that *Capoeta capoeta gracilis* (= *C. razii*) of the southern Caspian Sea is a distinct species, sister to *C. heratensis*. They also determined that there are three main *Capoeta* clades (only Iranian or potentially Iranian species noted here): the *Capoeta trutta* group including *mandica* and *trutta* characterised by having numerous irregular black spots on the dorsal half of the body, this clade being the sister group to all other *Capoeta* species and considered as the Old Evolutionary Group, the *Capoeta damascina* group including *birunii* (= *coadi*), *buhsei*, *coadi*, *damascina* (not in Iran as now understood and see below), *ferdowsii*, *pyragyi*, *saadii*, *shajariani* and *umbla*, the Young Evolutionary Group, and the *Capoeta capoeta* group including *Capoeta gracilis* (*sic*, presumably *C. razii*) and *heratensis* (and *alborzensis* (= *aculeata*) and *fusca* after Jouladeh-Roudbar *et al*. (2017)) characterised by large scales, a plain body and a distribution in the Aralo-Caspian region, the Very Young Evolutionary Group. Zareian and Esmaeili (2017) gave details of genetic distances, classification matrix, principal component analysis, discriminant function scores, haplotype networks, diagnostic nucleotide substitutions and Bayesian trees for the *C. damascina* group.

Ghanavi *et al*. (2016) investigated the phylogenetic relationships of *Capoeta* species in Iran using cytochrome *b*. They confirmed the existence of three main clades (Mesopotamian, Anatolian-Iranian and Aralo-Caspian) which diverged around 15.6-12.4 MYA consistent with a Mio-Pleistocene origin of *Capoeta* diversity in Iran. The Mesopotamian clade diverged from the other two clades ca. 15.6 MYA (13.8-17.2 MYA) which separated ca. 12.4 MYA (10.5-14.4 MYA). Changes in Caspian Sea level and uplift of the Zagros and Alborz mountains may account for the complex speciation pattern observed in Iranian *Capoeta*. They add to the Aralo-Caspian clade three undescribed species from the Tejan (= Tajan) River, the southern Caspian Sea basin (from the Atrak to the Sefid and Qezel Owzan rivers) and the Namak Lake basin (Jaj and Namrud, the latter actually in the Dasht-e Kavir basin), and to the Anatolian-Iranian clade three undescribed species from the Dez, Karkheh and Zohreh river basins, with *C. aff. aculeata* in the Karkheh River basin. *C. coadi* was also found in the Zayandeh River basin where it could be a distinct species.

Alwan *et al*. (2016) examined species ascribed to the *Capoeta damascina* species complex using mitochondrial and nuclear DNA sequences. The name *C. damascina* was long used for fishes occurring from the Levant, Mesopotamia, Turkey and Iran, with various synonyms. These are reviewed below with illustrations of types. The occurrence of *Capoeta damascina* in Iran now requires confirmation (see below).

The syntypes of *Gobio damascinus* described from the “fleuve de Damas” (= river of Damascus, Syria) are in the Muséum national d’Histoire naturelle, Paris (MNHN 4494 (now 0000-4494), 2 specimens, 169-179 mm standard length, Damascus, Syria, Bové, MNHN 3948, 1, 289 mm standard length, Nahr Barada, Syria and MNHN A.3947, 1, 169 mm standard length, Syria) (Krupp, 1985c). Bertin and Estève (1948) gave 200-210 mm total length for MNHN 4494 and 330-390 mm total length for MNHN 3947, 3948 and A.789. Eschmeyer *et al*. (1996) listed MNHN 4494 as the lectotype (as designated by Krupp and Schneider (1989) although this collection comprises two fish) with MNHN 3947 (1, dry) and MNHN 3948 (1, dry) and possibly MNHN A.789 (1) as paralectotypes. The latter is listed as a syntype in Bertin and Estève (1948) although the localities listed in this article “Fl. Jourdain, à Damas (Syrie)” is obviously an error on geographical grounds.

*Capoeta damascina*, lectotype, MNHN-IC-0000-4494, L. Randihasipara (CC BY 4.0).


*Capoeta damascina*, lectotype, dorsal view, MNHN-IC-0000-4494, L. Randihasipara (CC BY 4.0).

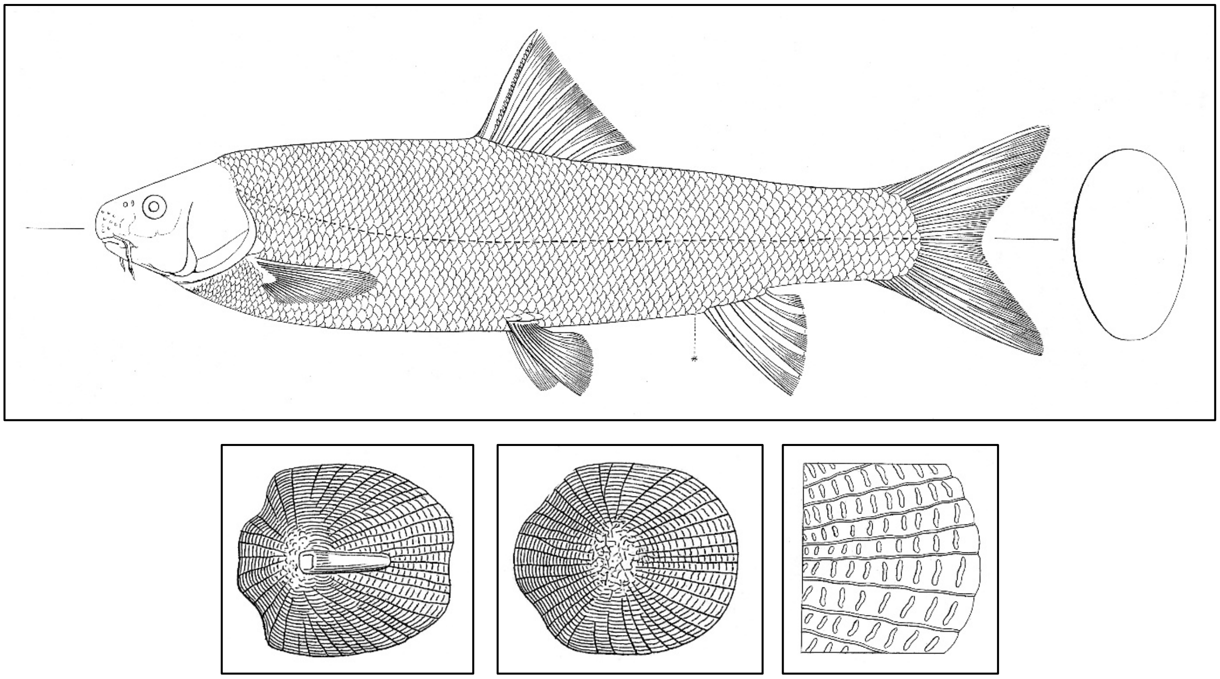

*Capoeta damascina*, lectotype, ventral view, MNHN-IC-0000-4494, L. Randihasipara (CC BY 4.0).

Specimen identified as *Capoeta damascina* (not kept), ~250 mm standard length,
Kermanshah, Sirvan (or Sirwan) River,
after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

Synonyms of *C. damascina* are *Scaphiodon capoeta* Heckel, 1843 (*non sensu* Güldenstädt, 1773) described from "Aleppo", *Scaphiodon fratercula* Heckel, 1843 described from "Gewässern von Damascus", *Scaphiodon socialis* Heckel, 1843 described from "Um Damascus" (= around Damascus) (Heckel, 1843b) and later more completely from the "Orontes" (Heckel, 1847a) (placed in *Scaphiodon Capoëta* of Heckel by Steindachner (1864)), *Scaphiodon peregrinorum* Heckel, 1843 described from "Aleppo" and later from "Fluss Kueik bei Aleppo", and *Chondrostoma syriacum* Valenciennes, 1844 from Abraham's River at the foot of Mount Sinai, Egypt (the correct locality is probably in the Jordan River basin (Coad and Krupp, 1994)), and possibly *Barbus belayewi* Menon, 1960 (Menon and Yazdani (1968) dated this species as 1960, presumably the 1956 edition of the journal was delayed) from the "Tigris,

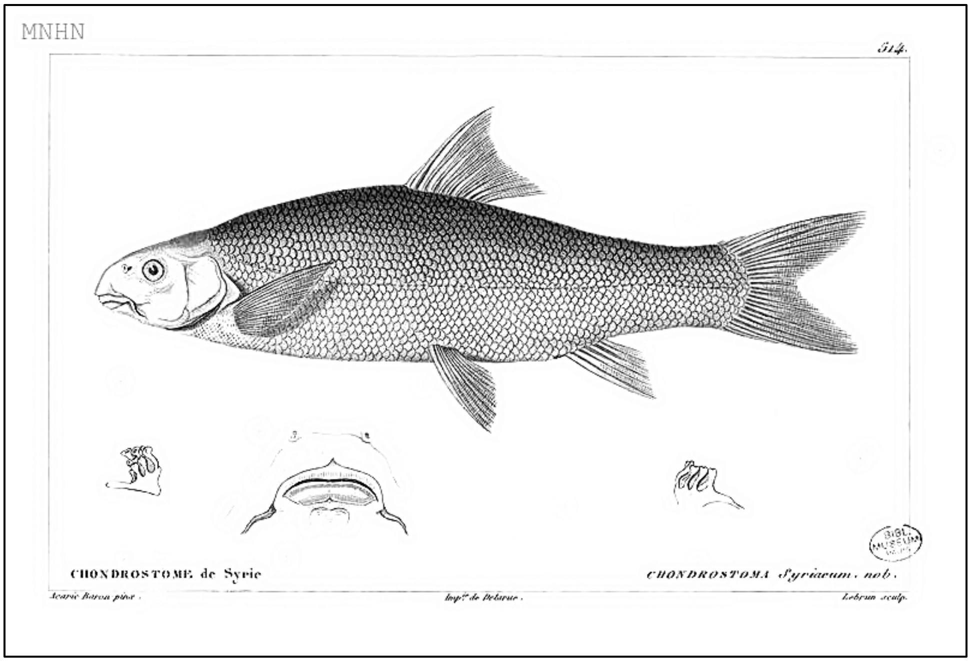
Baghdad, Iraq”. The synonymy of *Barbus belayewi* was suggested by F. Krupp (*in litt*., 1986) and W. Rainboth (pers. comm., 1986). The synonymy of *S. fratercula* was pointed out by Berg (1949) since the species was founded on low lateral line scale counts, a variable character in *C. damascina*, and on a larger orbit but Heckel’s comparison was between fish of greatly differing size and no allowance was made for allometry.

Syntypes of *Scaphiodon capoeta* are in the Naturhistorisches Museum Wien under NMW 51650 (1 fish), NMW 51831 (1), and NMW 55845-55846 (2). Heckel (1843b) listed two specimens in his description. Alwan (2010) pointed out that these fish are *C. damascina* but cannot be *Scaphiodon capoeta* types as the size of the fish does not agree with the description.



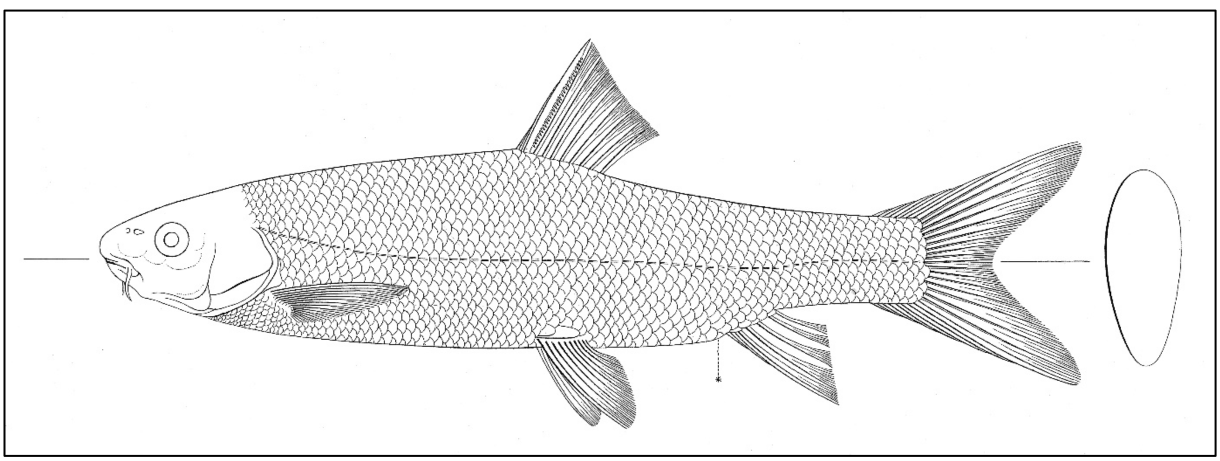
*Scaphiodon capoeta*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

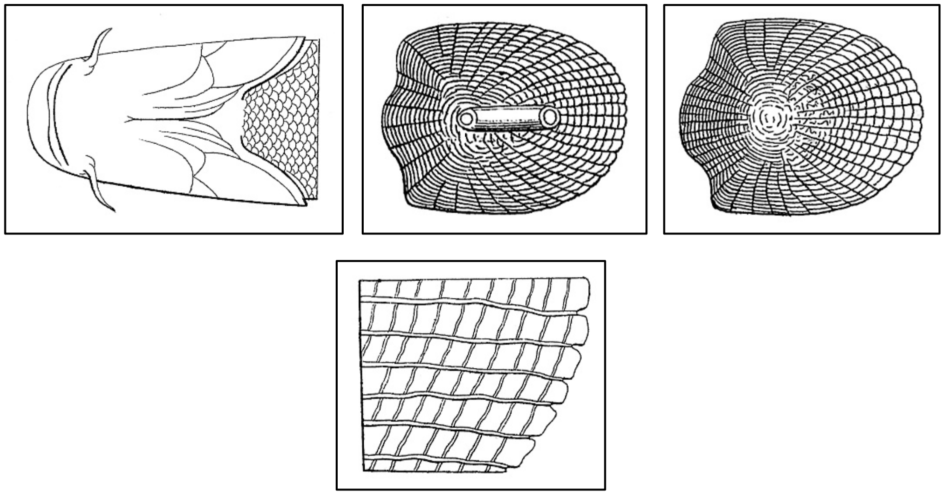
The holotype of *Chondrostoma syriacum* is in the Muséum national d’Histoire naturelle, Paris under MNHN 1945, now 0000-1945 (Eschmeyer *et al*., 1996).




*Chondrostoma syriacum*, syntype, body, ventral head and pharyngeal teeth, after Valenciennes (1844).

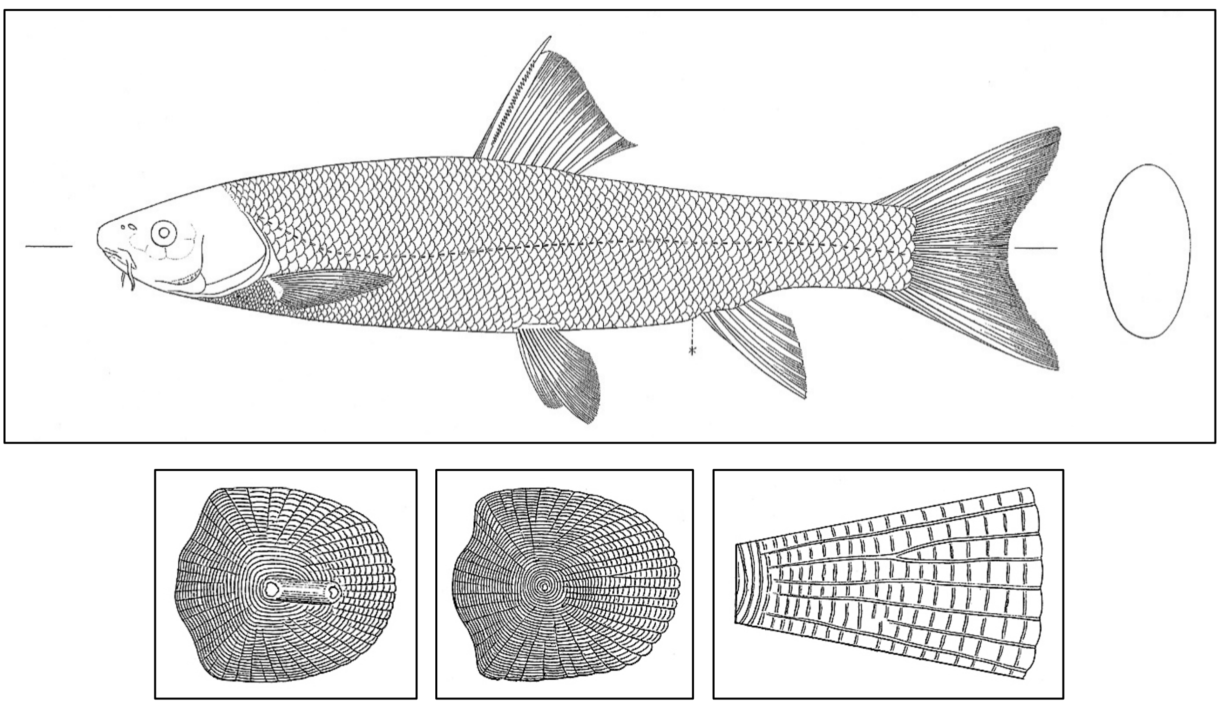
The holotype of *Scaphiodon fratercula* was taken from “Gewässern von Damascus”, the types of *Scaphiodon socialis* from “Um Damascus” (but listed as “Orontes” in the catalogue in Vienna, possibly in confusion as this part of the catalogue has been overwritten), and the types of *Scaphiodon peregrinorum* from “Um Aleppo” according to Heckel (1843b) and “Fluss Kueik bei Aleppo” according to Heckel (1847a). Eschmeyer *et al*. (1996) and Alwan (2010) noted that there are no types of *Scaphiodon fratercula* in the Naturhistorisches Museum Wien.





*Scaphiodon fratercula*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

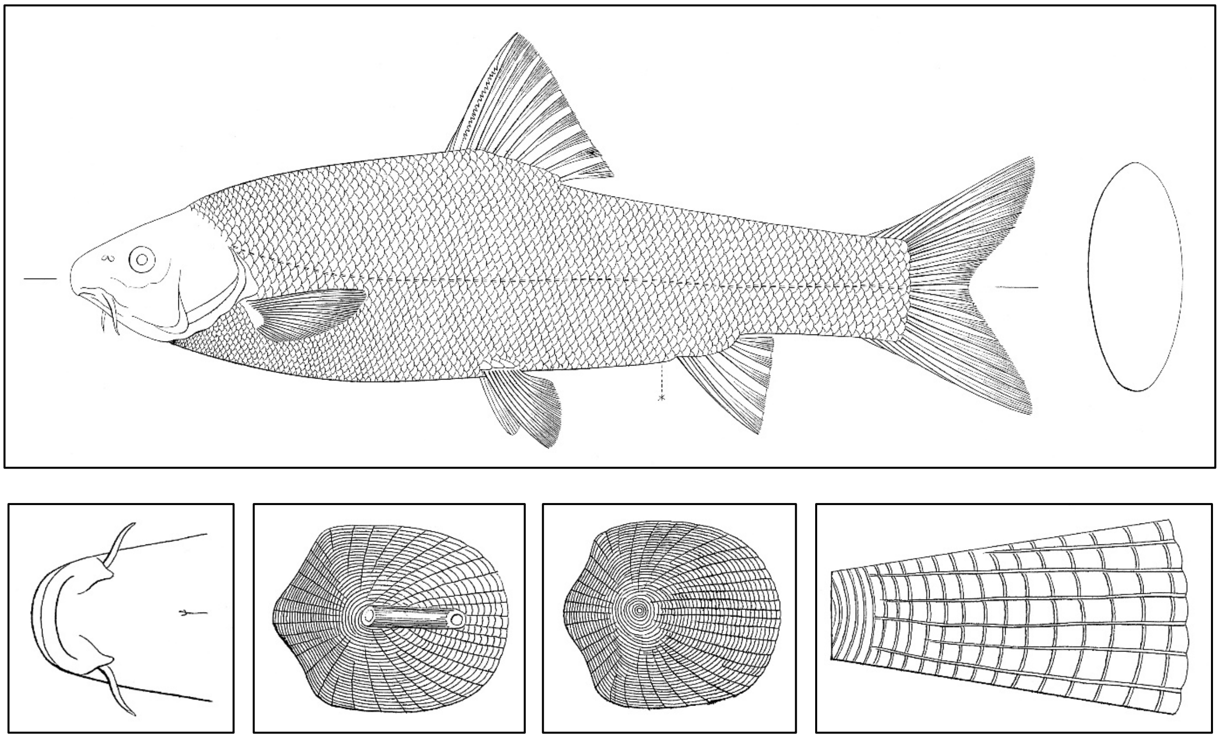
Two fish are labelled as syntypes of *Scaphiodon socialis* in the Naturhistorisches Museum Wien (NMW 55855) which agrees with Heckel's text although the catalogue listed only one specimen. Eschmeyer *et al*. (1996) stated that there are no types at NMW presumably after Krupp and Schneider (1989) who stated that NMW 55670 (1 fish), 55843 (2) and 55855 (2) are not types.



*Scaphiodon socialis*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

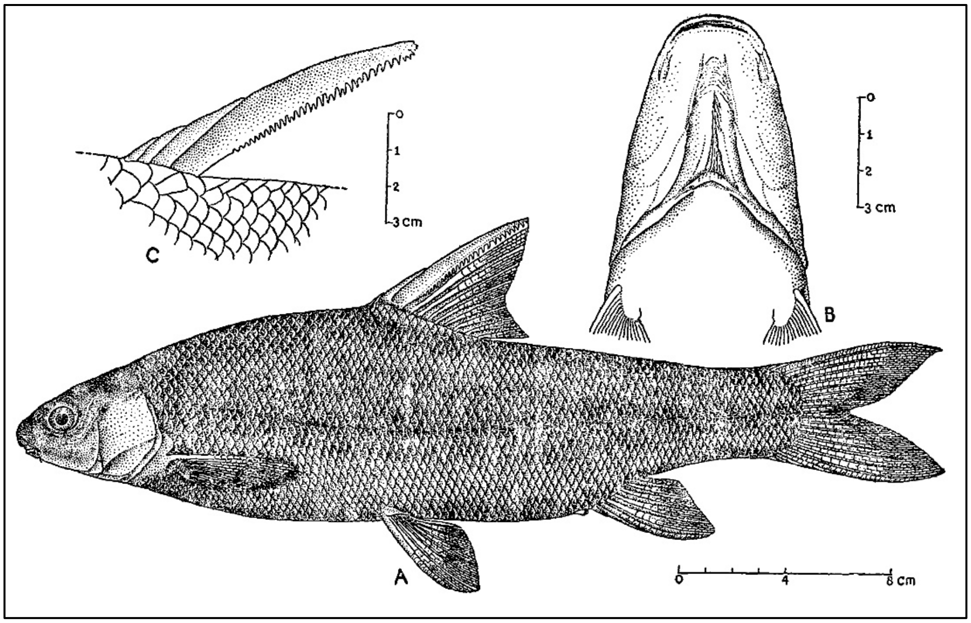
The types of *Scaphiodon peregrinorum* number six according to the catalogue in the Naturhistorisches Museum Wien and may comprise all or part of NMW 51658 (1), NMW 51659 (1), NMW 51660 (1), NMW 51661 (1), NMW 51662 (1), NMW 51663 (1) NMW

51664 (3), and NMW 51665 (1), all labelled as from “Kueik” and possibly RMNH 2681 (3) in the Rijksmuseum van Natuurlijke Historie, Leiden from NMW (Eschmeyer *et al*., 1996; Alwan, 2010).



*Scaphiodon peregrinorum*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

The types of *Barbus belayewi* are in the Zoological Survey of India, Calcutta, the holotype being ZSI F1046/2 and a paratype ZSI F1047/2 (Menon, 1960; Menon and Yazdani, 1968).



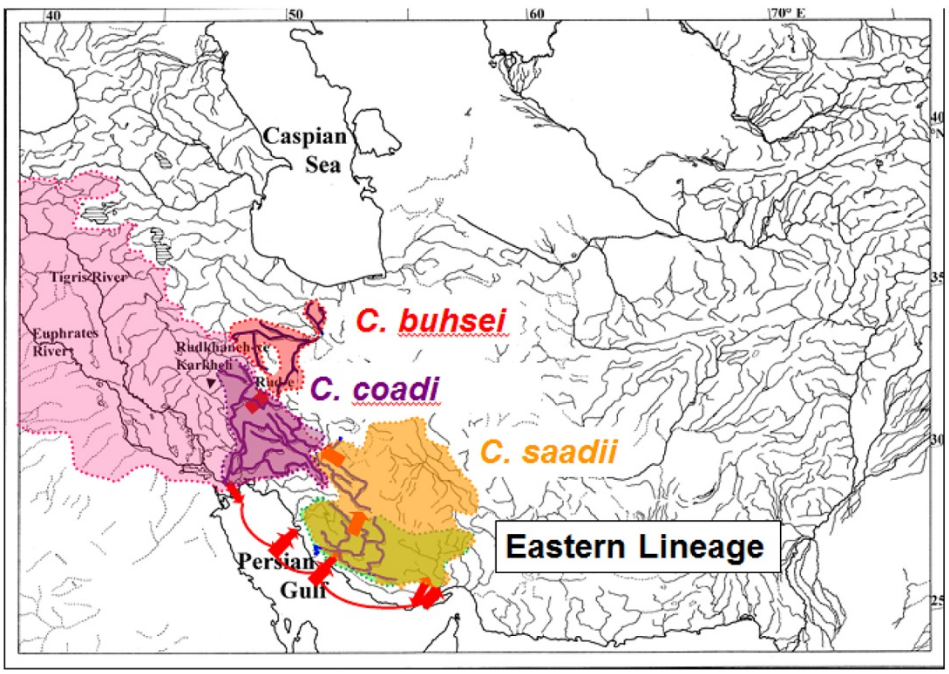

*Barbus belayewi*, A = holotype, B = ventral head of paratype,
C = serrated dorsal spine of paratype, after Menon (1960).

Karaman (1969a) placed *damascina* in *Capoeta capoeta* as a subspecies and *umbla* as another subspecies. Berg (1949) and Saadati (1977) recognised *umbla* as a distinct species. The latter is distinguished from the former by a higher scale count (87-99), higher dorsal fin branched rays (9-10), longer dorsal fin, longer caudal fin (shorter than or equal to head length in *C. damascina*), a markedly transverse mouth, and a weaker dorsal fin spine. Saadati (1977) considered *fratercula* to be a distinct species from the Tigris and Mond rivers in Iran based on scale count (58-66), more gill rakers (20-22), and a more serrated dorsal fin spine; or a subspecies of *Capoeta capoeta* based on a close similarity in scale counts, average number of gill rakers, and the dorsal fin origin being anterior to that of the pelvic fins. He also considered that *Scaphiodon niger* from the Kor River of Fars as possibly a synonym of *fratercula*. Krupp (1985c) considered the synonymy of *C. damascina* and *C. capoeta* as extremely doubtful after examining topotypic material.

Samaee and Patzner (2011) examined fish identified as *C. damascina* from six river systems (Ghárásu, Hánnã, Bãzoft, Eghlid, Ãbãdeh and Gãmãsiyãb) in Iran morphometrically and were able to distinguish distinct groups. However, as they pointed out, much more work needed to be done to determine if this variation was genetic differentiation or phenotypic plasticity, or a combination of the two. Razavipoor *et al*. (2015) examined fish identified under this name from the Tigris, Kerman (*sic*), Jaz Murian, Persis, Hormuz, Esfahan and Namak Lake basins using morphometry finding significant differences associated with body depth, fin positions and the caudal peduncle shape. The Namak Lake population was the most distinctive. Razavi Pour *et al*. (2015) examined 150 specimens from five, widely-separated localities in the Iranian Tigris River basin and found significant differences in snout length, head width, the position of the pectoral and pelvic fins and caudal peduncle depth, attributed to differing environmental conditions. These papers encompass several new and resurrected species as listed below.

*Capoeta damascina* is now restricted to fish from Syria, Lebanon and Palestine/Israel and does not occur in Iran (Alwan, 2010). Ghanavi *et al*. (2016) stated that it is probably only

in the Sirvan River in the Tigris River basin in Iran, and Shirmohamadi *et al*. (2017) and Jouladeh-Roudbar *et al*. (2017, 2020) recorded it from there but this needs molecular evidence and comparison with *C*. *umbla* given the variation in morphology of related *Capoeta* species. *C*. *saadii* and *C*. *umbla*, previously referred to *C*. *damascina* by various authors, are recognised as distinct along with newly described species *C*. *coadi*, *C*. *ferdowsii*, *C*. *pyragyi* and *C*. *shajariani* and are found in Iran (see map below). However, the phylogenetic relationship between *C*. *damascina* and *C*. *umbla* was not well resolved but specimens of *C*. *umbla* clustered together and form a monophyletic group. Incomplete lineage sorting, mitochondrial transfer in the recent past (introgression), or both can account for this incomplete resolution. *C*. *damascina* is known to hybridise with other unrelated species so introgression seems likely. *C*. *buhsei*, an Iranian species long recognised as distinct, is also part of the *C*. *damascina* species complex, along with *C*. *caelestis* Schöter, Özuluğ and Freyhof, 2009 from the Göksu Nehri in Turkey. An eastern lineage of the *C*. *damascina* species complex comprises *C*. *buhsei*, *C*. *coadi* and *C*. *saadii* with *saadii* the sister group to *buhsei* and *coadi*, the latter two closely related.



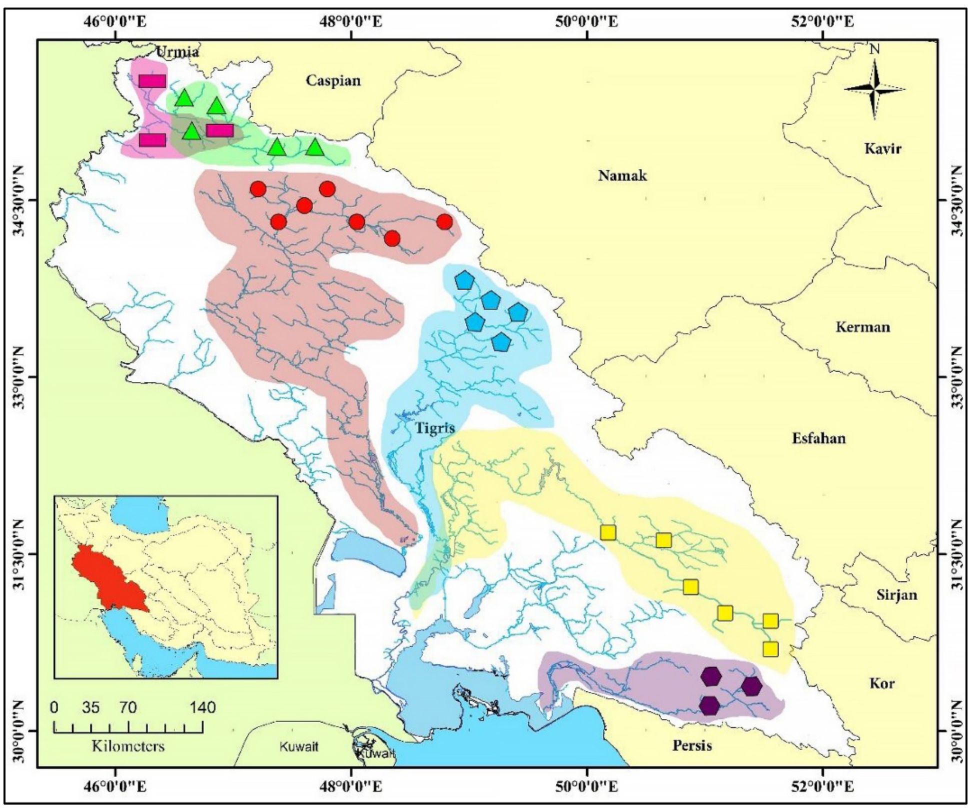

*Capoeta damascina* species complex eastern lineage, after Alwan *et al*. (2016).

The western lineage is comprised of *C*. *caelestis*, *C*. *damascina* and *C*. *umbla*. The authors assumed that the ancestor of the *C*. *damascina* species complex reached the rivers of the Persian Gulf and Strait of Hormuz basins during the Pleistocene glacials when sea level dropped, the Persian Gulf dried up completely and a river valley connected the waters of Mesopotamia to the rivers of the Persis and Hormuz basins. There it differentiated giving rise to the eastern lineage. As the Kor River basin was part of the Mond River drainage during that time, the ancestor of *buhsei*, *coadi* and *saadii* most probably reached the Kor River through this connection. It possibly re-invaded part of the Tigris-Euphrates system and from there moved on to the Namak Lake basin through headwater capture during wetter periods of the Pleistocene. The population in the Persis, Kor River and Hormuz basins evolved into *C*. *saadii* and made its way into other basins by headwater capture during Pleistocene wet periods as

river headwaters are close on high plains in southern Iran. The sister population from the Iranian Tigris and Namak Lake basins later split into *C. coadi* and *C. buhsei*. Part of the western lineage, after separation from the eastern lineage, most probably differentiated in the Tigris-Euphrates basin into *C. damascina* and *C. umbla*.

Jouladeh-Roudbar *et al*. (2017) used cytochrome *b* and morphological and meristic characters to examine the *Capoeta* of the Caspian Sea basin in Iran. They summarised previous papers as indicating *C. gracilis* was found from the Sefid to Atrak rivers and *C. capoeta* was found in the Kura-Aras and the Lake Urmia basins. The status of *C. gracilis* was uncertain as it was originally described from the Esfahan basin in central Iran. Their analysis found two species in the southern Caspian Sea basin, *C. capoeta* and a new species *C. razii* (*Capoeta* sp. 1 in Ghanavi *et al*. (2016)) that differed from species in the Esfahan basin. The Esfahan basin contained only *C. aculeata* and *C. coadi*.

Jouladeh-Roudbar *et al*. (2017) examined the small-scaled members of the *Capoeta damascina* group in the Tigris River basin of Iran and described three new species, *C. ferdowsii*, *C. pyragyi* and *C. shajariani* based on morphology and DNA evidence. Their distribution is given, along with three other species, in the following map:-




Distribution of *Capoeta coadi* (square), *C. damascina* (triangle), *C. ferdowsii* (hexagon), *C. pyragyi* (pentagon), *C. shajariani* (circle) and *C. umbla* (rectangular), after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

Bektas *et al*. (2017) analysed Anatolian *Capoeta* using the cytochrome *b* gene. They found taxa became isolated in freshwater basins from the middle Miocene to the late Pleistocene (about 13.75-0.41 million years) by tectonic uplift and faulting and, more recently, by climate changes. Comparative Iranian samples were distinguished as species but *C. saadii* was cited as

a subspecies of *C. damascina*. *C. heratensis* appeared as a subspecies of *C. capoeta* or as a distinct species.

Zareian *et al*. (2017) summarised the distribution of all *Capoeta* species in Iran, mapping seven of nine species of the *C. capoeta* group, eight of 11 species of the *C. damascina* group and three of six species of the *C. trutta* group. The highest species richness was found in the Tigris River basin for this genus in Iran and species were distributed in all Iranian basins except those in southeast Iran (Hamun-e Jaz Murian, Makran, Hamun-e Mashkid, Sistan).

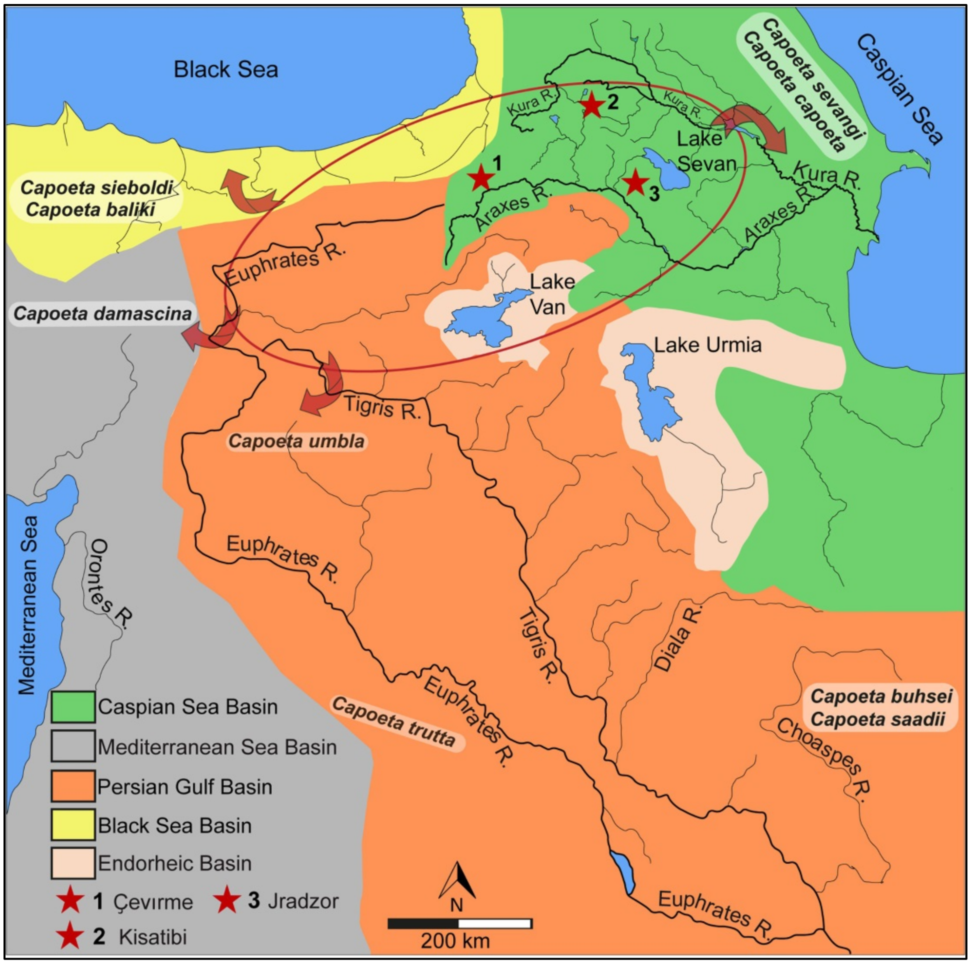
Zareian *et al*. (2018) summarised and confirmed the existence of the *Capoeta capoeta* complex as comprising nine taxa and reviewed it based on morphological characters and mitochondrial genes. *Capoeta macrolepis* was revalidated as a distinct species and, with *Capoeta fusca*, is an additional member of the complex. The genus *Capoeta* comprises three highly divergent lineages, the *Capoeta trutta* group (Mesopotamian group), the *Capoeta capoeta* group (Aralo-Caspian group) and the Anatolian-Iranian group (including the *Capoeta damascina* group). A molecular time tree showed that the separation of *Capoeta* from its relative *Luciobarbus* was about 12.43-16.99 MYA. Based on this tree, the high diversity of *Capoeta* in the Tigris-Euphrates basin, the nesting of *Capoeta* within the tetraploid *Luciobarbus* in the mitochondrial trees and the high diversity of *Luciobarbus* in the Tigris-Euphrates basin, it was proposed that *Capoeta* originated and diversified in the palaeodrainages of the Tigris-Euphrates basin. From here, dispersion of *Capoeta* to the other nearby basins could have been possible through freshwater corridors during the Pliocene or Pleistocene. The headwaters of the Tigris-Euphrates basin interdigitate with upper reaches of the Caspian Sea basin (the Aras and Qezel Owzan rivers in Iran, for example), the Lake Urmia basin with both the Caspian and Tigris River basins, endorheic basins (Namak Lake and Esfahan, for example) with eastern Tigris River basin tributaries, and the endorheic Kor River basin with the Tigris River basin via a Palaeo-Kor River.

Zareian *et al*. (2018) further stated that the first clade to diverge in *Capoeta* was the Mesopotamian group. Its separation occurred in the Middle Miocene about 14.35 MYA (9.94-16.65), and the separation of two other clades (Aralo-Caspian and Anatolian-Iranian groups) occurred 9.4 MYA (6.37-12.3). These divergences are mostly in agreement with Levin *et al*. (2012). Following this *C. anamisensis* separated at 1.83 MYA (0.92-3.05) and *C. trutta* at 1.33 MYA (0.57-2.32). Species of the *C. trutta* group, the earliest diverged lineage of the genus (*C. barroisi* Lortet, 1894 (not in Iran), *C. mandica*, *C. trutta*, *C. turani* Özuluğ and Freyhof, 2008. (not in Iran)), all have single pair of barbels without a horseshoe-shaped lower jaw (Karaman, 1969 - although jaw shape is age-related in my samples). The Anatolian-Iranian clade includes species widespread throughout the Anatolian peninsula and river basins of western and central Iran. This well-supported clade was the most diverse among *Capoeta*, consisting of six subclades. Support for these relationships included posterior probabilities ranging from 1 to 0.81 for cytochrome *b* and 1 to 0.87 for COI genes. Members of this group have 2-4 barbels and a horseshoe-shaped lower jaw (Karaman, 1969 - see above) and some of them (e.g., *C. saadii* from Iran) displayed intrapopulational variability in the number of barbels (two, three or four after Nikol'skii (1938), Levin *et al*. (2005, 2012), Alwan *et al*. 2016, and data herein).

The *Capoeta capoeta* complex group includes the large-scale taxa *C. aculeata*, *C. capoeta*, *C. ekmekciae* Turan, Kottelat, Kirankaya and Engin, 2006 (not in Iran), *C. fusca*, *C. gracilis*, *C. heratensis*, *C. macrolepis*, *C. sevangi* (not in Iran) and *C. razii* with genetic distances ranging from 0.38 to 2.94% for COI and 0.60-3.53% for cytochrome *b* genes. These fishes mostly having two barbels while some (e.g., *C. heratensis*) often have four barbels. It

was proposed that species of *Capoeta* with four barbels are more basal than species with only two as all species of *Luciobarbus* have four barbels (Karaman, 1969; Levin *et al*., 2012). However, this hypothesis may not be supported based on the phylogenetic relationships of the three *Capoeta* species groups. Species of the *C. trutta* group, the earliest lineage to diverge in the genus, have two barbels. Members of the two other clades have 2-4 barbels. It therefore appears that the number of barbels may be retained in some taxa, whereas other species could rapidly lose them independently of their branch (see Levin *et al*. (2012)) due to the specialization required to scrape algae from stones. It has been proposed that the number of barbels is an evolutionarily reversible character in *Capoeta* (Levin *et al*., 2012). The clade of the *Capoeta capoeta* complex group is formed by two recently diverged subgroups approximately 3.3 MYA (1.99-5.01) in Zareian *et al*. (2018) and 2.6 MYA in Levin *et al*. (2012). The main diversification events of the species belonging to these two groups occurred during the Pliocene. The first subgroup includes *C. capoeta*, *C. ekmekciae* and *C. sevangi* de Filippi, 1865 that are widespread in the Kura and Aras Rivers and Lake Sevan drainages (western Caspian Sea basin with only the first in Iran). The interrelationships of these species were not well-resolved. The second subgroup comprised a well-supported subgroup of species (bootstrap values of 98% to 99%) distributed in central and eastern parts of the South Caspian Sea basin from the Sefid to Atrak rivers and the northern part of the Dasht-e Kavir basin (*C. razii*), in the Tedzhen or Hari River basin (*C. heratensis*) and also from isolated waterbodies in the Dasht-e Lut basin (*C. fusca*).

Ayvazyan *et al*. (2019b) presented an unusual hypothesis regarding *Capoeta* evolution in the 4 MYA old Tekman Palaeolake, Erzurum Province, in eastern Anatolian Turkey, at the Pliocene age locality Çevirme, based on isolated pharyngeal teeth from lake sediments. The Pliocene lake constituted sympatric occurrence of four *Capoeta* species (*C. cf. umbla*, *C. cf. baliki*, *C. cf. sieboldi* and *C.* sp. *sevangi*/*capoeta*), whose modern relatives belong to a monophyletic clade inhabiting today three different drainage systems of this region (Euphrates River, Kura River and Black Sea). They interpreted this high local diversity of closely related species in terms of a species-flock model. The Tekman Palaeolake was a part of an unrecognized extended late Miocene to Pliocene palaeolake system in the present-day Armenian Highland, which was disrupted by Pliocene tectonic activities. Surface uplift of the Armenian Highland contributed to the characteristic biogeographic distribution and endemism of *Capoeta* in West Asian drainage systems. Their conclusions are summarised below in the figure and its caption.




Geographical overview of the drainage systems of the Western Asia and the Ponto-Caspian regions (Euphrates-Tigris, Araxes-Kura), after Ayvazyan *et al*. (2019b). The red circle shows the possible extension of the palaeolake system of the Armenian Highland. The arrows show the late distribution of the recorded fossil *Capoeta* species into the different water basins due to the tectonic disruption of the Lake system during the Pliocene uplift period. The two already known late Miocene fossil sites Kisatibi (red star 2) and Jradzor (red star 3) are included as well (CC BY 4.0).

The number of vertebrae has also been proposed to be an important taxonomic character, at least in the *C. capoeta* complex group by Levin *et al*. (2005). This complex is clearly subdivided into two groups: multivertebrate (including *C. capoeta* and *C. sevangi* with vertebrae = 45-48) and oligovertebrate (*C. gracilis* (= *razii*), *C. heratensis*, and *C. steindachneri* Kessler, 1872 (this latter not in Iran) with vertebrae = 41-45). Morphometry and longevity also differ between these two groups and it was assumed that they belong to different phyletic lines, relationships corroborated based on the mtDNA sequences of two genes in Zareian *et al*. (2018).

The genus *Capoeta* comprises medium-sized to large cyprinids and is characterised by a compressed to rounded and moderately elongate body, small to moderately large scales (lateral line counts 32-104), scales at the anal fin base and anus not usually enlarged (sometimes variably enlarged as is the case with certain cyprinids but not the specialised scales of schizothoracines), an inferior, transverse mouth, the lower jaw with a sharp, horny sheath,

barbels usually in one pair, more rarely two pairs, dorsal fin short (usually 7-9 branched rays) with the last unbranched ray thickened and bearing serrations (serrations sometimes reduced to absent), anal fin short (usually 5 branched rays), gill rakers short, moderate to numerous, pharyngeal teeth in three rows with spoon-shaped and truncate tips, a very long and coiled gut (ca. 7-10 times body length), mostly of uniform colour, and a black peritoneum. Dehghani Firoozabadi *et al*. (2014) found the lapillus in *C. aculeata*, *C. damascina* (*sic*), *C. gracilis* (*sic*, presumably *C. razii*) and *C. trutta* was the largest otolith and had species-specific characters.

The general name for the members of this genus in northern Iran is siah mah, meaning black fish) while in the south they are called twiny, touyeni, tu'ini gelkhorak or gel cheragh, meaning mud-eater or mud-grazer, e.g., in Khuzestan. The name *Capoeta* derives from the Armenian and Georgian name for female *Capoeta capoeta* packed with eggs, namely "Kapwaeti". Other general names for members of this genus, shol khar, ghel khar or choul khar, are all variant spoken intonations meaning mud-eater. The English common name is scraper.

Zareian *et al*. (2015) used Species Distribution Modeling to predict climatically suitable habitats for *Capoeta* species in Iran using 19 climatic variables. Climatically suitable areas for most species are restricted mainly to the western half of Iran but suitable areas lacking species were also detected.

Nasrolah Pourmoghadam *et al*. (2019) assessed habitat suitability indices for *Capoeta alborzensis* (= *C. aculeata*), *C. buhsei* and *C. razii* in the Jaj, Kordan and Taleghan (= Taleqan) rivers measuring a wide range of environmental variables. Suitable habitats were those with a high stone diameter, high temperature, neutral pH, sufficient dissolved oxygen, low flow velocity and areas where the width of the river was low. Higher levels of phosphate, nitrate and ammonium increased phytoplankton, the preferred food of *Capoeta*, and therefore fishes to a certain extent. These factors may apply generally across *Capoeta* species. It was also noted that fish in the Taleqan River found suitable habitats remote from the dam on that river.

Raissy *et al*. (2009) identified parasites generally from *C. aculeata*, *C. damascina* (*sic*, presumably *C. coadi*) and *C. capoeta gracilis* (*sic*, the latter species not occurring there) in the Kyar and Beheshtabad rivers of Chahar Mahall and Bakhtiari Province, Tigris River basin as *Ichthyophthirius multifilis* and *Trichodina* sp. (Ciliophora), *Myxobolus musayevi* (Myxozoa), *Dactylogyrus lenkorani*, *D. pulcher*, *Dactylogyrus* spp., *Gyrodactylus* sp. (Monogenea), *Allocreadium isoporum*, *A. pseudaspii* and *A. laymani* (Digenea), *Bothriocephalus gowkongensis* (Cestoda), *Rhabdochona* sp. (Nematoda), and *Lamproglena chinensis* (Crustacea).

The larger *Capoeta* species are fished for sport and food in Iran, e.g., Samaee and Patzner (2011) and Bahrami Kamangar *et al*. (2015).

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Various past studies were carried out on fish identified as *C. damascina* and these were re-assigned here based on distribution to the presumed appropriate and recently-described species. However, some localities are in river basins where the taxon is unknown as they were not part of the taxonomical studies where putative *C. damascina* collections were recognised as a distinct species. These basins are mostly those on the Iraqi border in the Tigris River basin and in the southern Esfahan basin. A number of studies cited below are on fish from the Qeshlaq River (and Azad Dam and Komasi River) near Sanandaj and Lake Zaribar west of

Sanandaj, Kordestan and these may be *C. umbla* (and/or *C. damascina* according to Jouladeh-Roudbar *et al*. (2017)) or possibly an undescribed taxon. Given this uncertainty, these studies are not assigned to a known species. Morphometric and meristic characters for Iranian Tigris River basin taxa were not always clearly distinctive ("characters in combination"), showed overlap, and were based on as few as nine specimens. DNA evidence was used to separate and define the new taxa but this cannot be applied, obviously, to older preserved material.

Literature studies on these unidentified *Capoeta* collections from the Tigris River basin of Iran are given below under the usual headings:-

**Morphology.** Razavi Pour *et al*. (2014) described the osteology of the species from the Tigris River basin (Gheshlagh (= Qeshlaq) River). Zadmajid *et al*. (2018) described embryonic and early larval development, from egg activation to the exogenous feeding period for fish from the Qeshlaq River.

**Age and growth.** Esmaeili and Ebrahimi (2006) gave a significant length-weight relationship based on 40 Iranian fish without a defined locality measuring 5.23-19.87 cm standard length, having a *b* value of 2.89. Hasankhani *et al*. (2013) gave a *b* value of 3.425 (in abstract, 3.223 in table) for 47 fish, 4.94-14.25 cm total length, from the Sirvan River in the Tigris River basin.

Bahrami Kamangar *et al*. (2015) examined 147 fish, 4.58-37.2 cm fork length, from the Gheshlagh (= Qeshlaq) River and Dam. The overall sex ratio was female biased (1:1.79), males lived to 4 years and females to 5 years, and the length-weight relationship was $W = 0.021L^{2.815}$ for males, $W = 0.22L^{2.824}$ for females and $W = 0.02L^{2.836}$ for combined sexes, all showing negative allometric growth. The von Bertalanffy growth parameters were $L_{inf}$ = 34.81 cm, k = 0.27 year$^{-1}$ and $t_0$ = -0.65 for males plus unsexed samples, $L_{inf}$ = 46.29 cm, k = 0.22 year$^{-1}$ and $t_0$ = -0.59 for females plus unsexed samples, and $L_{inf}$ = 67.52 cm, k = 0.12 year$^{-1}$ and $t_0$ = -0.79 for whole samples. The population could be overexploited. Fazli *et al*. (2018) studied fish from Azad Dam Lake (90 fish) and the Komasi River (40 fish). Total length and weight were 5.1-35.0 cm and 2.5-465.0 g in the river and 12.0-26.0 cm and 14.7-216.0 g in the dam lake, the length group of 18.1-19.0 cm prevailed (14.2%) followed by the length group of 17.1-18.0 cm (12.6%) of the total catch, the length-weight regression was $W = 0.0122FL^{2.9338}$, the male:female sex ratio was 1:0.47 for adults which differed significantly from the expected 1:1 ratio, the age range was 1-7 years with ages 3 and 4 the most dominant age groups (55.9%). the von Bertalanffy growth parameters were estimated as $L_\infty$ = 373.3 mm, K = 0.17/yr and $t_0$ = -0.58/yr, the instantaneous coefficient of natural mortality was estimated at 0.36/yr, the average condition factor values were 1.13 and 0.98, and the relative condition factors were 1.11 and 0.98, in the river and the lake, respectively. This population showed an isometric growth pattern, where rapid growth occurred during the two first years of life. The relative condition values showed that the fish were in good condition in the Azad Dam and the Komasi River.

**Food.** Afraei Bandpei *et al*. (2019) described the food of fish identified as *Capoeta saadii* from the Azad Dam. The rate of relative gut index was 2.7, indicating the species was herbivorous, and the gastrosomatic index was 449.2. The condition factor (K) was 0.47 indicating moderate obesity. The copepod crustacean *Mesocyclops* was the most consumed item in spring at 52% along with the water flea *Bosmina longirostris* at 48%. In summer, the green alga *Spirogyra* comprised 43% and *Bosmina longirostris* 26.7% of the diet. In autumn, only the branchiopod crustacean *Diaphanosoma brachyurum* was found.

**Reproduction.** The following two articles are on fish in the Esfahan basin and could refer to *C. coadi* but this remains uncertain as records of that species are currently restricted

there to the Zayandeh River basin. Gharache (2008) studied fish from a qanat in southern Isfahan Province and found a male:female sex ratio of 1:0.7, absolute fecundity was 1,190-19,620 eggs, mean 9,715 eggs, relative fecundity was 58-839 eggs/g, mean 339 eggs/g, and spawning was in April and May. Soofiani and Asadollah (2010) found fish from the Hanna Wetland, Semirom had a male:female sex ratio of 2.2:1, an absolute fecundity of 2,023-36,763 eggs and spawning was in May-June.

Bahrami Kamangar *et al*. (2015) examined fish from the Gheshlagh (= Qeshlaq) River and Dam where spawning started in May, increased in June and ended in July, water temperatures were 16-22°C and mean day length was 14.0-14.5 hours, length at 50% maturity was estimated at 12.35 cm for males and 15.14 cm for females, the youngest mature male was in age class 1 and the youngest female in age class 2, maximum egg diameter was 1.75 mm, and fecundity ranged from 1,551 eggs for two-year-olds to 20,523 eggs for five-year-olds. Early June at mean water temperatures of 18-20ºC was given as the reproductive period in the Qeshlaq River, Sanandaj (Zadmajid *et al*., 2018). Afraei Bandpei *et al*. (2019) in their fish identified as *Capoeta saadii* from the Azad Dam, found an average gonadosomatic index of 4.41, lowest in autumn at 1.1 and highest in spring at 9.4.

**Parasites and predators.** Jalali *et al*. (2002) and Jalali and Barzegar (2006) recorded *Trichodina pediculus*, *Dogielius molnari*, *Gyrodactylus* sp., *Dactylogyrus carassobabrbi* and *D. lenkorani* from fish identified as *C. damascina* in Lake Zaribar. Jalali Jafari and Miar (2011) summarised the metazoan parasite community in nominal *C. damascina*, presumably encompassing a number of species now, in the Mesopotamian region, identifying 54 species. Maleki *et al*. (2018) recorded metacercariae of the trematode *Clinostomum complanatum* from fish identified as *C. damascina* in the Qeshlaq River basin.

**Experimental studies.** Pirbeigi *et al*. (2013) found that fish identified as *C. damascina* (possibly *C. buhsei* but uncertain) in the Namak Lake basin could be used as an indicator species for the pesticide diazinon as various haematological parameters (e.g., red and white blood cells and lymphocytes) decreased on exposure while the neutrophil count increased. Pirbeigi *et al*. (2016) found that the blood, liver, gill and kidney of their *C. damascina* from the Kordan River were sensitive enough to low concentrations of the pesticide diazinon that it could be used as a bioindicator.

Nematollahi *et al*. (2013) isolated and characterised macrophages from the spleen and head kidney in fish identified as *C. damascina* as these are important in disease resistance. The locality not given, possibly the upper Tigris River basin.

Zadmajid *et al*. (2018) found that ovaprim, a commercial spawning inducing agent, stimulated spermiation, modulated steroidogenesis and testicular development in wild-caught fish but hCG (human chorionic gonadotropin) did not, and hCG exerted negative effects on gamete quality. Zadmajid and Butts (2018) found that a dosage of 0.5 ml/kg of sGnRHa + domperidone (gonadotropin releasing hormone stimulating follicle release + a prolactin releaser, promoting sexual maturation) assisted reproduction. Zadmajid *et al*. (2019) found using frozen-thawed sperm from fish (from the Qeshlaq River, and it is assumed the previous two papers seen only in abstract also used fish from this river) had an embryonic vitality of 34-49% and impaired embryonic and larval development. Frequencies and position of abnormalities were given and normal and abnormal larvae illustrated.

Bahrami Kamangar *et al*. (2012b) provided baseline haematological and biochemical indices for this species in Gheshlagh (= Qeshlaq) Dam, Kordestan that could be used in health monitoring.

Adel *et al*. (2020) evaluated propofol and clove oil anaesthetics on fish from the Arvand River and recommended propofol instead of clove oil due to rapid induction, longer duration and more prolonged effect in the immersion method.

**Sources.** Iranian material:- The following material represents specimens that are not assigned to a species. Their distribution falls in areas on the map by Jouladeh-Roudbar *et al*. (2017) (see above) where no species is identified. The small-scaled species of the Tigris River and adjacent northern Persis basin in Iran (*C. coadi* , *C. ferdowsii*, *C. pyragyi* and *C. shajariani*) are morphologically quite similar and are defined more by distribution and DNA. Preserved and non-retained material is not readily identifiable.

CMNFI 1979-0288, 51, 37.6-153.7 mm standard length, Ilam and Poshtkuh, Gangir River at Juy Zar (33º50'N, 46º18'E); CMNFI 1979-0289, 1, 41.8 mm standard length, Kermanshah, river in Diyala River drainage (34º28'N, 45º52'E); CMNFI 1979-0290, 1, 44.1 mm standard length, Kermanshah, river in Qasr-e Shirin (34º31'N, 45º35'E); CMNFI 1979-0291, 2, 22.8-30.3 mm standard length, Kermanshah, river in Diyala River drainage (34º24'N, 45º37'E); CMNFI 2008-0120, not kept, Khuzestan, Rud Zard at Rud Zard (31º22'N, 49º43'E); CMNFI 2008-0121, not kept, Khuzestan, Zard Rud at Bagh-e Malek (31º32'N, 49º55'E); CMNFI 2008-0161, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 2008-0163, not kept, Khuzestan, Marun River at Chahar Asiab (30º40'28"N, 50º09'34"E); CMNFI 2008-0171, 1, 39.6 mm standard length, Khuzestan, A`la River at Pol-e Tighen (31º23'20"N, 49º52'44"E); CMNFI 2008-0175, not kept, Lorestan, Kahman River at Dow Ab-e Aleshtar (33º47'N, 48º12'E).

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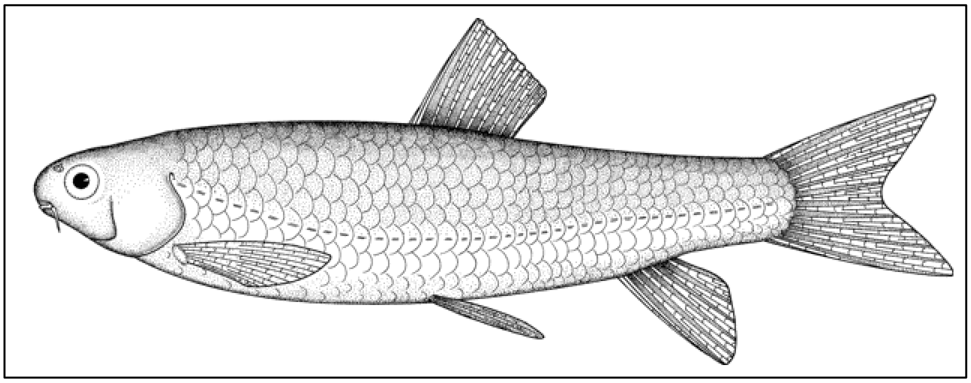
Some fish are not readily identifiable on morphology alone as noted above. Another example, a large-scaled species under CMNFI 2007-0071, was collected on 29 November 1974 from a qanat at a mosque in Mohammadiyeh, a suburb of Na'in at about 32°51'N, 53°06'E in Esfahan Province. This sample is in the Kerman-Na'in basin bordering both the Namak Lake and Esfahan basins, and has scale (lateral line 42-47) and gill raker (23-25) counts that could identify the fish as *C. aculeata* or fish erroneously ascribed to *C. gracilis* (see below under the latter species). In the absence of molecular information, the pre-DNA sample cannot be ascribed to a species, although further refined and detailed morphological studies may help. Other samples show characters that are a mix of two species and may represent hybrids, a wider range in the characters than currently understood, or a new taxon. Again, molecular data would be needed to clarify this situation and an example of this problem can be seen in the *C. aculeata* account. Nonetheless some species are clearly distinguished by morphological and field characters without DNA analyses. DNA analyses in recent species descriptions form the basis of species distinction but see the comments by Palandačić *et al*. (2017) given in **Methods**. Distribution is often an important consideration.

Saadati (1977) noted in his thesis that three specimens were recorded as an unknown *Varicorhinus* (= *Capoeta*) from the Malekabad qanat in Markazi (CMNFI 2007-0076), in the Namak Lake basin, with a recorded lateral line scale count of 50-60 although he found no specimens with these counts in the collection. Their identity remains uncertain. Other *Capoeta* from this locality were *C. cf. aculeata* and possibly *C. buhsei* (scale counts for both were anomalous). Another unknown *Varicorhinus* (= *Capoeta*) of Saadati (1977) was from a qanat south of Abarqu in Fars (CMNFI 2007-0068), listed incorrectly as in the Zayandeh River basin, is identified here as *Capoeta saadii* from the Sirjan basin (see below).

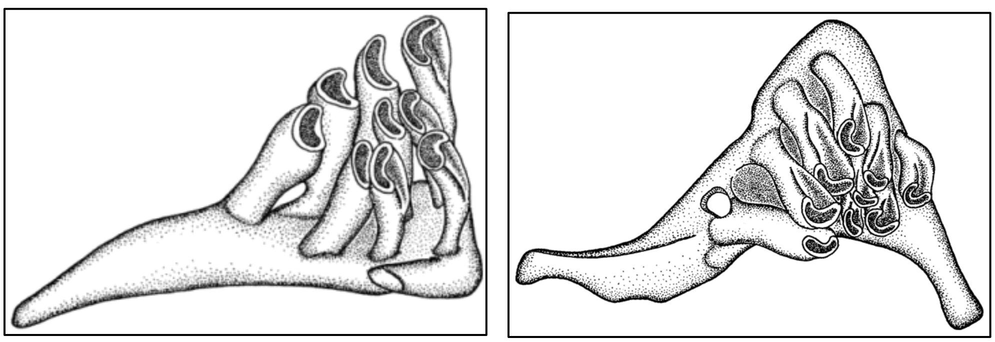
The table below summarises some characters. Data is from literature sources and material examined in this book and, when expanded beyond a single study, some characters used to define a species within that single study then overlap. Morphometric characters must be treated with care as sample sizes may be small (average about 16 fish per literature study) and no allowance is made for difference in size, sex, condition and habitat. The same author(s) also reported somewhat different count ranges for the same species within and between papers and, of course, different authors reported different ranges. This may be because different material is examined, a smaller or larger sample size is reported on, and possibly different counting methods.

| Species/ Characters | Lateral line scales | Dorsal fin branched rays | Scales above lateral line | Caudal peduncle scales | Total gill rakers | Distribution |
|---|---|---|---|---|---|---|
| *C. aculeata* | 36-52 | 8 | 6-10 | 13-23 | 16-25 | Namak Lake, western Dasht-e Kavir |
| *C. anamisensis* | 56-67 | 8 | 11-13 | 21-24 | 21-25 | Hormuz |
| *C. buhsei* | 72-99 | 8 | 12-17 | 26-33 | 9-19 (9-15) | Namak Lake, western Dasht-e Kavir |
| *C. capoeta* | 46-70 | 8 | 7-11 | 19-23 | 16-32 (21-32) | Caspian Sea (Aras River), Lake Urmia |
| *C. coadi* | 68-84 | 8 | 12-17 | 20-33 | 12-19 | Esfahan, Tigris River (Karun River basin) |
| *C. ferdowsii* | 68-83 | 8 | 13-17 | 23-30 | 13-18 | Persis (Zohreh River basin) |
| *C. fusca* | 40-62 (46-56) | 7 | 8-10 | 19-26 | 11-21 (14-17) | Bejestan, Dasht-e Lut, Dasht-e Kavir, Hari River, Sistan |
| *C. gracilis* | 51-60 | 8 | 9-11 | 20-23 | 18-23 | Esfahan |
| *C. heratensis* | 46-60 | 8 | 9-12 | 22-25 | 21-24 | Dasht-e Kavir, Hari River |
| *C. kaput* | 52-60 | 9 | 9-12 | 20-23 | 24-25 | Caspian Sea (Aras River) |
| *C. macrolepis* | 37-51 | 8 | 6-9 | 15-21 | 16-25 | Kerman-Na'in, Kor River, Persis, Tigris River |
| *C. mandica* | 57-68 | 8 | 12-16 | 25-33 | 21-30 | Hormuz, Persis |
| *C. pyragyi* | 63-81 | 9 | 12-16 | 24-29 | 15-19 | Tigris River (Dez River basin) |
| *C. razii* | 39-59 (49-57) | 8 | 7-11 | 17-26 | 15-26 | Caspian Sea (other than Aras River), possibly northern Dasht-e Kavir |
| *C. saadii* | 58-83 (61-79) | 8 or 9 | 9-16 | 23-28 | 9-20 | Dasht-e Lut, Hamun-e Jaz Murian, Hormuz, Kerman-Na'in, Kor River, Lake Maharlu, Persis, Sirjan |
| *C. shajariani* | 62-80 | 9 | 11-16 | 22-31 | 14-21 | Tigris River (Karkheh River basin) |
| *C. trutta* | 61-90 | 8 | 9-14 | 27-31 | 20-33 | Persis, Tigris River |
| *C. umbla* | 72-104 | 9 | 18-25 | 31-39 | 17-23 | Tigris River |

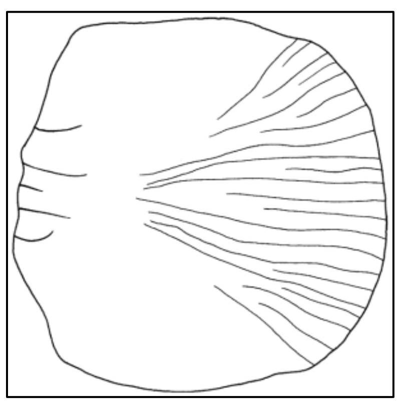
***Capoeta aculeata***
(Valenciennes, 1844)



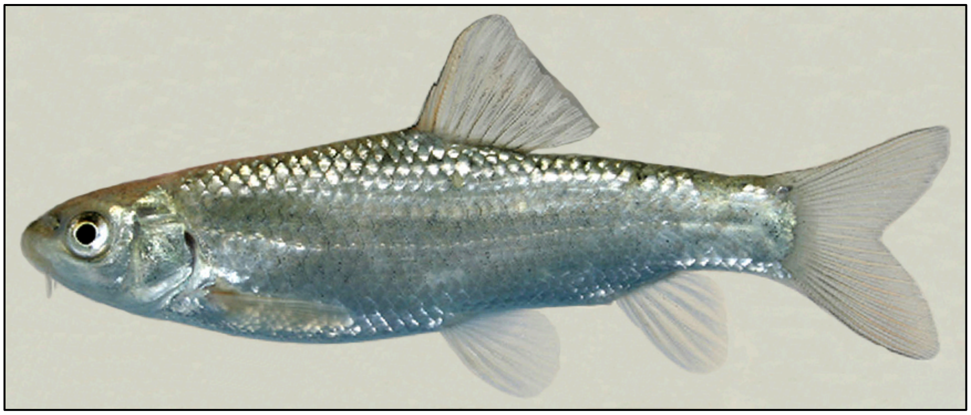
*Capoeta aculeata*
Freidhelm Krupp.



*Capoeta aculeata*, left pharyngeal arch views, Freidhelm Krupp.



*Capoeta aculeata*, scale,
Freidhelm Krupp.



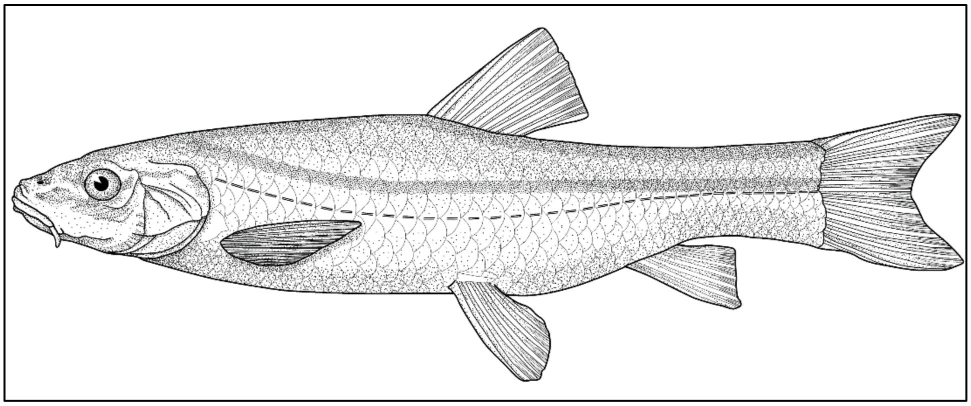
*Capoeta aculeata*, Qom, Qom River near Emamzadeh Abdollah, Hamid Reza Esmaeili.

*Capoeta aculeata* (as *C. alborzensis*), 106.7 mm standard length, IMNRF-UT-111, Tehran, Nam River, after Jouladeh-Roudbar *et al*. (2016).

**Common names.** Shum (= unlucky or inauspicious, possible meaning), siah mahi (= black fish), zardehpar (in reference to yellow fins), siah mahi aculeata, siah mahi polk dorosht, siahmahi-ye fals dorosht (= large scale black fish); siyah mahi Alborz for *C. alborzensis*.

[Common large scale scraper, large-scaled barb; Alborz scraper and Alborz large scale scraper for *C. alborzensis*].

**Systematics.** *Varicorhinus bergi* Derzhavin, 1929 described in Latin from "Keredsh flumen propea Teherane, Persia septentrionalis" (Karaj River near Tehran, northern Iran) is a synonym. Types of *Varicorhinus bergi* are unknown (Eschmeyer *et al*., 1996). *Capoeta alborzensis* Jouladeh-Roudbar, Eagderi, Ghanavi and Doadrio, 2016 is a synonym after Zareian *et al*. (2018) based on molecular evidence.



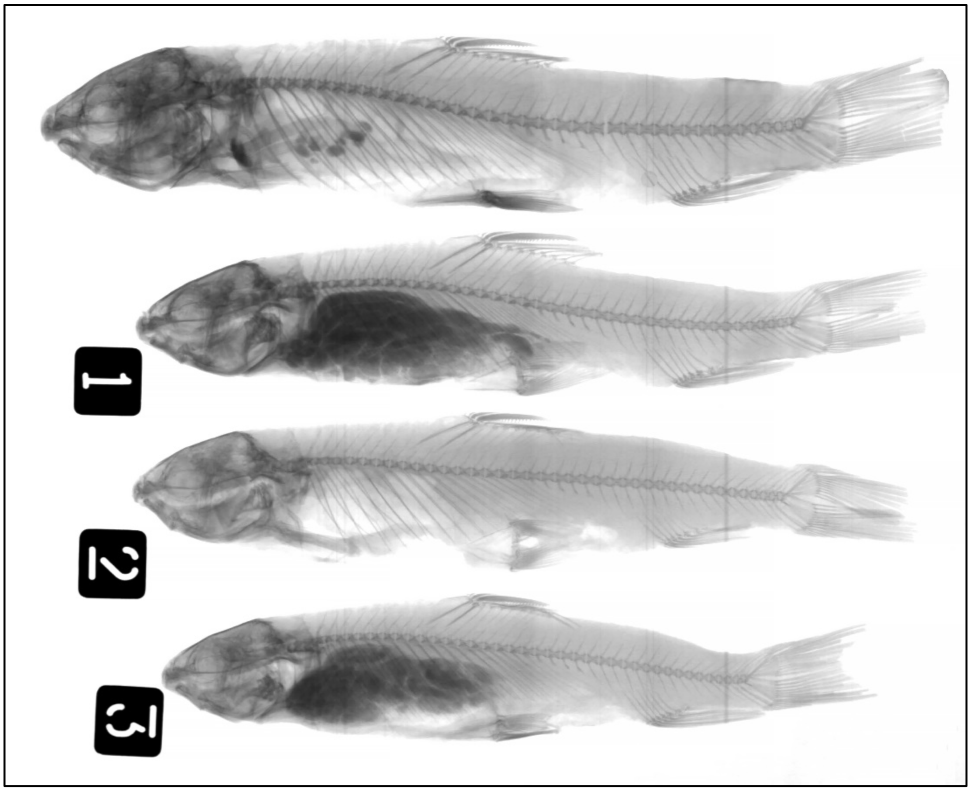
*Varicorhinus bergi*, after Derzhavin (1929),
re-drawn by Susan Laurie-Bourque @ Canadian Museum of Nature.

Six syntypes (MNHN 2357 or 0000-2357) of *Chondrostoma aculeatum* are stored in the Muséum national d'Histoire naturelle, Paris (Bertin and Estève, 1948; Coad and Krupp, 1994). They measure 8.6-17.9 cm standard length (Coad and Krupp, 1994) or 10.5-21.0 cm total length (Bertin and Estève, 1948). The largest specimen is designated as the lectotype under the original number and the rest of the syntypes are now under 1960-0611 (and are not fish from the Jajrud River (= Jaj River) as mentioned in Jouladeh-Roudbar *et al*. (2020)).


*Chondrostoma aculeatum*, MNHN-IC-0000-2357,
L. Randrihasipara (CC BY 4.0).


*Chondrostoma aculeatum*, MNHN-IC-0000-2357,
L. Randrihasipara
(CC BY 4.0).

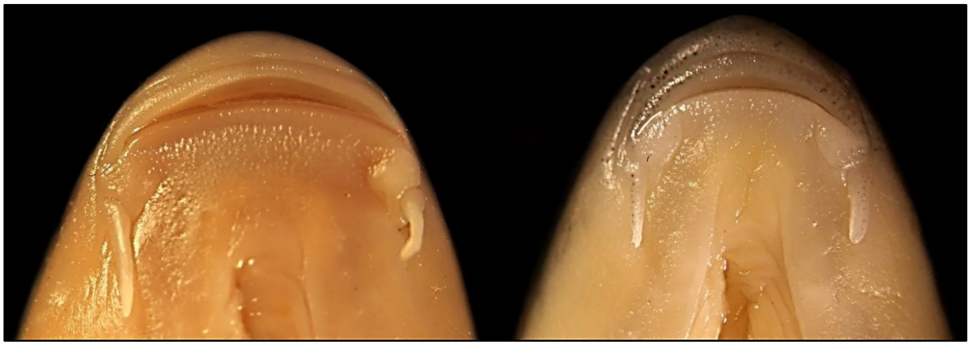

*Chondrostoma aculeatum*, MNHN-IC-0000-2357, S. Grosjean and M. Silvain
(CC BY-NC-ND 4.0).




*Chondrostoma aculeatum*, MNHN-IC-0000-2357, S. Grosjean and M. Silvain (CC BY-NC-ND 4.0).

The holotype of *C. alborzensis* is under IMNRF-UT-1063-115 (Ichthyological Museum of Natural Resources Faculty, University of Tehran, Karaj), 108.5 mm standard length, Tehran Province, Nam River, tributary of Hableh River, near Harandeh village, 35°42'41.1"N, 52°40'19.7"E, and paratypes are IMNRF-UT-1063, 7, 48-136 mm standard length, data same as holotype and IMNRF-UT-2063, 23, 40-163 mm standard length, Tehran Province, Nam River, tributary of Hableh River, near Arjomand village, 35°48'00.1"N, 52°30'57.8"E.

*Capoeta alborzensis*, holotype, after Jouladeh-Roudbar *et al*. (2016).



Ventral view of heads of *Capoeta aculeata*
(left, IMNRF-UT-058-120, 100 mm standard length)
and *Capoeta alborzensis* (right, IMNRF-UT-115, 108 mm standard length),
after Jouladeh-Roudbar *et al*. (2016).

Last unbranched dorsal fin ray or spine in *Capoeta aculeata* (above)
and *Capoeta alborzensis* (below), both fish ≈100 mm,
after Jouladeh-Roudbar *et al*. (2016).

Berg (1949) considered *C. aculeata* and *C. macrolepis* as distinct species although very close, the latter distinguished from the former by a deeper body and a shorter head. Karaman (1969a) and Bianco and Banarescu (1982) placed both *aculeata* and *macrolepis* in *Capoeta capoeta*; Karaman did suggest that *macrolepis* could belong in *aculeata*. Saadati (1977) considered *aculeata* not more than subspecifically distinct from *macrolepis*, not realising the former has priority. Zareian *et al*. (2018) distinguished *C. macrolepis* from *C. aculeata* based on three fixed diagnostic nucleotide substitutions in the mtDNA cytochrome *b* and one in COI, while morphological characters overlapped.

Babaei *et al*. (2014) using the COI gene found that *C. capoeta* was the closest relative, diverging 1.9 MYA. Babaei *et al*. (2017), however, cited divergence at 4.24-5.1 MYA. This latter study using the COI gene found fish from the qanats of the Ardestan and Namak basins in Tehran Province were the same, those of the Naieen region were different from other regions, and those from the Karun (presumably *C. macrolepis*) and Namak basins were closely related.

*Chondrostoma aculeatum* was originally described from “eaux douces de la Perse”. The assumption has been that the types were collected in the vicinity of Tehran (the Namak Lake basin), as mentioned in Berg (1949) and Zareian *et al*. (2018) although Jouladeh-Roudbar *et al*. (2020) summarised recent authors stating the types were collected from a southern basin. However, the collector Aucher-Éloy traveled from Baghdad to Hamadan, Esfahan, Tehran and Tabriz in 1835 and in 1837-1838 he visited Shiraz, Bushehr, Bandar-e Abbas, the Bakhtiari

mountains and the south coast of the Caspian Sea. Confusingly, *Leuciscus maxillaris* Valenciennes, 1844 from "rivières de Perse" was collected by Aucher-Éloy and is a synonym of *Alburnus sellal*, a southern species while *Leuciscus albuloides* Valenciennes, 1844 from "des mêmes eaux que la précédent" is possibly a synonym of *Alburnus chalcoides,* a northern species. Aucher-Éloy may have meant Persian rivers in general rather than the exact same locality. There are no field data and the collection of *Chondrostoma aculeatum* was recorded as Aucher-Éloy ("Collection date 1840", presumably when received in Paris, not collected, after Bertin and Estève (1948)) so the locality cannot be fixed to a particular basin in Iran. A type locality cannot be subsequently fixed arbitrarily. If the type material was collected from the Kor River or Tigris River basins then the name *C. aculeata* applies to southern material and *C. macrolepis* (described from the Kor River basin) is a synonym. On the basis that *C. aculeata* was described from southern rivers, the Namak Lake and Dasht-e Kavir material were then described as *C. alborzensis* (but see below). Zareian *et al*. (2018), however, considering the Namak Lake basin as the type locality synonymised *C. alborzensis* with *C. aculeata*. Previously, *C. macrolepis* was considered to be a synonym of *C. aculeata* so the type locality being obscurely "eaux douces de la Perse" was not a problem. The type material of *C. aculeata* is in poor condition and meristics and morphometrics for the types are not definitive for either *C. aculeata* or *C. macrolepis* which are generally defined by distribution and DNA.

Jouladeh-Roudbar *et al*. (2020) also applied the name *C. aculeata* to fish in the Kor River and Tigris River basins and included *Varicorhinus bergi* (type locality in the Namak Lake basin) as a synonym. This latter taxon would be the correct name for Kavir and Namak fish and a new species description would be unnecessary. The problem is unresolvable on present data and placing *C. aculeata* in southern basins and describing a new species for the Kavir and Namak basins adds an additional layer of complexity without evidence.

**Key characters.** This species is distinguished from other large-scaled *Capoeta* species (60 or less lateral line scales) by having one pair of barbels, modally 8 dorsal fin branched rays, and a distribution in the Namak Lake and western Dasht-e Kavir basins. The predorsal scale rows (to one side of the dorsal mid-line) are 13-20 (21-30 in *C. fusca* for comparison). Meristic characters overlap with *C. macrolepis* including predorsal scales (13-21) used in a key by Zareian *et al*. (2018) (where they had equal to or less than 15 in *aculeata* and greater than 15 in *macrolepis*). These latter authors, however, distinguished *C. aculeata* from all other *Capoeta* in having one fixed, diagnostic nucleotide substitution in the mtDNA cytochrome *b* and two in COI.

**Morphology.** The body is rounded and relatively shallow. The greatest body depth is at the dorsal fin origin level. The predorsal body profile is straight to slightly convex. There is a weak keel in front of dorsal fin origin. The small mouth is ventral in a shallow horseshoe-shape or even straight with a horny edge to the lower jaw. The horny edge is usually well-developed but may be lost in preserved specimens. The upper lip is very small. The snout is rounded, and triangular in ventral view. The rostral cap is well-developed, partly overlapping the upper lip. The barbel extends back to the level of the anterior margin of the eye. The dorsal fin margin is straight to slightly concave. The depressed dorsal fin does not reach back to the level of the anal fin origin. The last dorsal fin unbranched ray is thickened and serrated, the denticles being long and narrowly spaced but not strongly developed. Distally this spiny ray is flexible. Smaller fish have proportionately larger and more extensive denticles than larger fish. The extent of denticles from the base distally varies between about two-thirds and three-quarters. The anal fin is rounded and does not reach back to, or just reaches, the caudal fin base. The

pelvic and pectoral fins are rounded. The pelvic fin is under the anterior third of the dorsal fin base. The pelvic fin does not reach back to the anal fin origin and the pectoral fin does not reach back to the pelvic fin origin. The caudal fin is moderately forked.

Dorsal fin with 3-5, modally 4, unbranched and 7-10, modally 8, branched rays, anal fin with 3 unbranched and 5-6, modally 5, branched rays, pectoral fin branched rays 14-21, and pelvic fin branched rays 7-10. Lateral line scales 36-52, predorsal scales 13-20, scales between dorsal fin origin and lateral line 6-10, and caudal peduncle scales 13-23. The pelvic fin axillary scale varies greatly in size and there may be two scales. It can be triangular and pointed. Scales on the belly anterior to the pelvic fins are smaller than elsewhere and heavily covered by skin and therefore difficult to discern. Predorsal scales are large. In large fish there are two lappets of skin and a free scale between the pelvic fin bases. Scale shape is squarish with shallowly rounded to straight dorsal and ventral margins, sharp corners anteriorly, and a large to moderate central protuberance on the anterior margin. Radii are most numerous on the posterior field but even there are few, and there are relatively few laterally and few anteriorly. Circuli are very fine but break into coarser tubercles on the posterior field. The focus is subcentral anterior. Total gill rakers number 16-25 and are short, reaching past the first or second raker when appressed. Rakers are thick and usually hooked at their tips. Pharyngeal teeth are modally 2,3,4-4,3,2. Major row teeth are spatulate with a wide crown in large fish. The gut is extremely elongate with numerous anterior and posterior coils. Total vertebrae number 38-44, perhaps lower counts omitting the four Weberian vertebrae.

Meristic characters in Iranian fish including the types in part (some characters damaged), excluding fish from the Dasht-e Kavir, and with dorsal fin branched rays in table below are:- anal fin branched rays 5(107), pectoral fin branched rays 14(2), 15(2), 16(8), 17(19), 18(46), 19(22) or 20(1), pelvic fin branched rays 7(10), 8(78) or 9(15), lateral line scales 36(1), 37(4), 38(8), 39(5), 40(8), 41(21), 42(23), 43(14), 44(10), 45(3), 46(3), 47(3), 48(1), 49(-), 50(-), 51(-) or 52(1), predorsal scale rows 13(5), 14(23), 15(35), 16(19), 17(10), 18(3), 19(2) or 20(1), scales between dorsal fin origin and lateral line scales 6(6), 7(37), 8(40), 9(11) or 10(1), around the caudal peduncle 13(1), 14(-), 15(3), 16(23), 17(16), 18(37), 19(9), 20(10), 21(1) or 22(1), total gill rakers 17(3), 18(7), 19(11), 20(22), 21(20), 22(18), 23(12), 24(5) or 25(1), and total vertebrae 40(4), 41(56), 42(35) or 44(5). Kiani and Keivany (2013) gave meristic characters for fish from the Qom River which fall within the above ranges.

Fishes from the northern Dasht-e Kavir (Kal-e Shur, Kal Yazd and neighbouring basins) are referred to *Capoeta cf. aculeata* here. They have characters intermediate and overlapping with *C. aculeata* and *C. fusca* as follows, with frequencies under each species based on my observations:-

| Character | *C. aculeata* | *Capoeta* Kavir | *C. fusca* |
|---|---|---|---|
| Dorsal fin branched rays | 7(9), 8(97), 9(1) | 7(43), 8(22), 9(2) | 7(77) |
| Predorsal scales | 13-20<br>(mostly 13-17, 94%) | 16-25<br>(mostly 17-24, 93%) | 21-30<br>(mostly 23-29, 96%) |
| Lateral line scales | 36-52<br>(mostly 37-44, 89%) | 39-51<br>(mostly 41-48, 90%) | 46-56<br>(mostly 46-54, 96%) |
| Total vertebrae | 40-43<br>(mostly 41-42, 91%) | 39-42<br>(mostly 40-42, 96%) | 40-43<br>(mostly 40-42, 95%) |
| Total gill rakers | 17-25<br>(mostly 18-24, 96%) | 16-25<br>(mostly 17-21, 90%) | 13-20<br>(mostly 14-17, 97%) |

For example, some fish from adjacent localities will have only or mostly 7 branched dorsal fin rays (as in *C. fusca*), a mix of 7 and 8 rays, or only 8 rays. This limited material may comprise some *C. aculeata* and *C. fusca*, be wholly one species with anomalous counts, be evidence of introgression, or be a new taxon. Zareian *et al*. (2018) indicated that material from the Dasht-e Kavir was *C. aculeata* apparently based on DNA evidence (COI and cytochrome *b* genes, a single Kavir sample, Semnan Province, Boneh Koh (= Bon-e Kuh) at 35º17'N, 52º24'E in the western Dasht-e Kavir basin immediately adjacent to the Namak Lake basin). Other Kavir records in this paper may be from my website were fish were then identified as *C. aculeata*. Both *C. aculeata* and *C. fusca* are mapped from the northern Kavir in Zareian *et al*. (2018).

Frequency distributions for Dasht-e Kavir fish are as follows (see table above for dorsal fin branched rays):- anal fin branched rays 5(53), pectoral fin branched rays 15(1), 16(2), 17(18), 18(23), 19(6), 20(2) or 21(1), pelvic fin branched rays 7(5), 8(38), 9(9) or 10(1), lateral line scales 39(1), 40(-), 41(4), 42(5), 43(10), 44(8), 45(4), 46(9), 47(3), 48(5), 49(1), 50(2) or 51(1), predorsal scale rows 16(1), 17(3), 18(2) 19(1), 20(11), 21(12), 22(9), 23(3), 24(4) or 25(2), scales around the caudal peduncle 17(2), 18(6), 19(14), 20(13), 21(8), 22(4) or 23(6), total gill rakers 16(2), 17(4), 18(9), 19(16), 20(13), 21(6), 22(1), 23(-), 24(1) or 25(1), and total vertebrae 39(2), 40(22), 41(18) or 42(10).

Some material is listed below as *C. cf. aculeata* from western drainages of the Namak Lake basin since some readily observable characters overlap or approach those of *C. buhsei* while others do not, both within a sample and on the same fish, e.g., intermediate lateral line scale counts (53-63), higher predorsal scale counts and (23-26) and scales above the lateral line (10), and overlapping total gill raker counts (16-18). This material has much smaller upper anterior flank scales than typical *C. aculeata* but does not have the higher scale counts of typical *C. buhsei*. These collections may represent hybrids, and so could have been listed under *C. buhsei*, as they were collected from the confines a qanat with fish identifiable as *C. aculeata* and *C. buhsei*. Or they may be anomalous or outlier specimens somewhat beyond the known regular limits for the species (some were sent to me and could well have been selected on this account). Larger sample series, more widespread collections and molecular work are needed to resolve this issue.

**Sexual dimorphism.** A fish from CMNFI 1979-0253 (103.7 mm standard length caught on 11 June 1977) has tubercles as follows, agreeing in general with literature reports. Males have moderately large tubercles on the anal fin rays following the ray branching (2-4 tubercles on the last 4 branched anal rays), small tubercles on the lowest caudal fin ray, very fine tubercles on top of the head, larger tubercles on the side of the head, largest on the snout below the eye and nostril as far as the mouth, connecting across the snout, smaller tubercles on the operculum, 1-5 moderately large tubercles distally on anterior flank scales variously arranged on each scale, and posterior lower flank scales from above the pelvic fins back to the caudal peduncle having 1-2 larger tubercles per scale.

**Colour.** The back is almost entirely black to green-brown, dark olive, olive-green, or a light golden, the upper flank is brownish, the belly and lower flank are yellow up to the lateral line, only the belly centre being white to dirty cream. The flanks are generally silvery to golden yellowish in live fish but may be brownish. Vague dark olive stripes extend parallel to the lateral line on the flanks. Some fish have small black spots on the sides and fins. The sides of the head are golden-brown. Flank spots on scales may be in 5-7 longitudinal rows above, and 2-4 rows below, the lateral line, or in some fish on all scales above the lower belly. Scales may only be outlined with pigment below the dorsal fin on the upper flank and posteriorly on the

body. Some populations have fish with spots and mottles on the body and fins but these are probably occasioned by a parasitic infestation. The upper head surface is light olive to golden yellowish. The operculum has a golden spot. Fins are often reddish-brown to pink although pelvic and anal fins may be yellowish-green and the dorsal and caudal fins very light to hyaline. The front of the dorsal fin and the dorsal and ventral margins of the caudal fin are yellow to orange. The pelvic and anal fins have a yellow or orange color on the base or on the first unbranched ray. Preserved fish have pigment on the rays and membranes of fins without any distinctive pattern. The dorsal and caudal fins are darker than the lower fins. The iris is golden to orange or silvery. The peritoneum is black.

**Size.** Reaches 37.3 cm total standard length (Esmaeili *et al*., 2014).

**Distribution.** This species is found in the Dasht-e Kavir and Namak Lake basins. In the Dasht-e Kavir basin it is recorded from the Hableh and Nam rivers and at Bon-e Kuh; and in the Namak Lake basin in the Ab Chay, Abhar, Abshine, Bhadorbarik, Damagh-Tasran, Eberu-Simin, Ekbatan, Fordoghan, Jaj, Kaleh, Karaj, Ken, Khar, Khenejin, Mazdaghan, Pol-e Doab, Qareh Chay, Qom, Salehabad, Sharra, Shur, Siah, Simineh, Taghra and Tonekabon rivers, Fin and Nazi springs, Soleiman Spring at Kashan and the 15 Khordad Dam (Abdoli, 2000; Touraji and Vosoughi, 2006; Abbasi, 2009; Alwan, 2010; Kiani and Keivany, 2013; Mousavi-Sabet and Eagderi, 2014; Jouladeh Roudbar *et al*., 2015, 2017; Alwan *et al*., 2016; Zareian *et al*., 2018; Nasrolah Pourmoghadam *et al*., 2019). Hashemzadeh Segherloo and Abdoli (2015) found a haplotype resembling this species in the Caspian Sea basin.

**Zoogeography.** Saadati (1977) suggested that this species moved eastward to basins on the plateau during more pluvial periods from the Tigris River basin. See also above under genus. Zareian *et al*. (2018) placed this species in the Aralo-Caspian group of *Capoeta* where it separated from *C. fusca* 1.52 MYA.

**Habitat.** This species is found in rivers, streams, wetlands, lakes, dams, springs, qanats and jubes (= irrigation ditches). As *C. alborzensis* it inhabits large streams and is more frequent in the main flow of large rivers. At the Nam River (type locality of *C. alborzensis*), temperature, pH and conductivity were 24°C, 7.1 and 0.675 µS, respectively. In addition, the current was medium to fast, river width about 2-17 m, maximum depth up to 1.5 m, the shore was grassy, and the stream-bed was composed of gravel. *Alburnoides coadi* (= *A. namaki*), *Barbus miliaris*, *Capoeta buhsei*, *Squalius namak*, *Oncorhynchus mykiss* (rainbow trout), and the loach *Paracobitis malapterura* co-existed with *C. alborzensis* at the type locality. Elsewhere this species was found generally at 15-28°C, pH 6.0-6.5, conductivity 0.85-3.7 mmhos, river width 0.5-10.0 m, depth 20-100 cm, slow to medium current, mud, sand, pebble or concrete bottoms, clear to cloudy water, encrusting and emergent vegetation and with tree roots, and grassy, bushy and forested shores.

Type locality of *Capoeta alborzensis*, Tehran, Nam River at Harandeh, after Jouladeh-Roudbar *et al*. (2016).

**Age and growth.** Unknown.

**Food.** Gut contents examined by me included filamentous algae, plant fragments and diatoms with large amounts of sand. This species has been seen turning belly up to feed (field notes for specimens from Jajarm, North Khorasan (possibly *C. aculeata* but see above under *Capoeta* Kavir).

**Reproduction.** Unknown.

**Parasites and predators.** None but see under *C. buhsei*.

**Economic importance.** None.

**Experimental studies.** Kamali-Far *et al*. (2009) have used common carp pituitary extract in an attempt to induce spawning in this species. Hatchery production could then be used to supplement natural stocks. However, the attempt was unsuccessful. Note that the identity of the species used in this study needs verification judging from the photograph in the paper.

**Conservation.** This species is widely distributed in Iran and does not appear to be in need of conservation, but its biology and habitat requirements are unknown. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern (as *C. alborzensis*) because it occurs in various independent localities and has no major threat apart from general drought.

**Sources.** Type material:- *Chondrostoma aculeatum* (MNHN 2357 and 1960-0611).

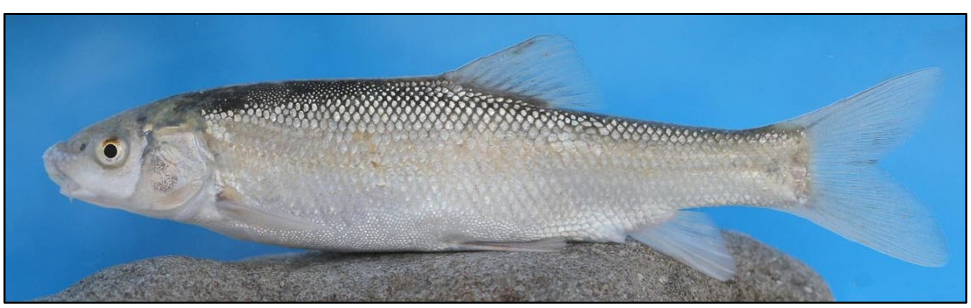
Iranian material:- CMNFI 1979-0252, 3, 52.9-56.1 mm standard length, Qom, jube at Baqerabad (34º55'N, 50º50'E); CMNFI 1979-0253, 5, 40.4-103.7 mm standard length, Qom, river in Qareh Chay drainage (34º52'N, 50º49'E); CMNFI 1979-0426, 9, 32.5-58.7 mm standard length, Esfahan, qanat at Abbasabad (33º36’N, 51º49’E); CMNFI 1979-0427, 2, 100.5-112.2 mm standard length, Esfahan, Cheshmeh Fin at Fin (33º57'N, 51º23'E); CMNFI 1979-0428, 17, 25.9-104.5 mm standard length, Esfahan, stream 3 km south of Sen Sen (34º13'N, 51º16'E); CMNFI 1979-0458, 9, 48.5-117.8 mm standard length, Qazvin, Khar River 6 km north of Ab-garm (35º47'N, 49º20'E); CMNFI 1979-0462, 6, 27.9-40.9 mm standard length, Markazi, Mazdaqan River (35º06'30"N, 49º40'30"E); CMNFI 1979-0463, 8, 97.9-135.3 mm standard length, Markazi, Qareh Chay (34º53'N, 50º24'E); CMNFI 1979-0464, 1, 73.4 mm standard length, Markazi, qanat at Kheyrabad (34º08’N, 50º00’E); CMNFI 1979-0465, 18, 35.7-58.3 mm standard length, Markazi, Qom River (34º18'30"N, 50º32'E); CMNFI 1980-

0156, 2, 34.5-50.5 mm standard length, Alborz, Karaj River (35º47'N, 50º58'E); CMNFI 1993-0156, 1, 100.4 mm standard length, Markazi, Sharra River (34º03'N, 49º21'E); CMNFI 2007-0074, 29, 50.6-100.7 mm standard length, Markazi, Qareh Chay 32 km west of Arak (34°03´N, 49°21´E); CMNFI 2007-0078, 8, 37.6-102.8 mm standard length, Markazi, Qom River (ca. 34º18'N, ca. 50º32'E); CMNFI 2007-0120, 15, 29.0-165.5 mm standard length, Hamadan, Ab Chay near Hamadan (ca. 34º49'N, ca. 48º29'E); CMNFI 2007-0122, 12, 35.0-77.6 mm standard length, Qazvin, Khar River basin south of Takestan (ca. 35º56'N, ca. 49º30'E); CMNFI 2008-0152, 1, 86.9 mm standard length, Namak Lake basin (no other locality data); BM(NH) 1934.10.29:2, 1, 84.0 mm standard length, Tehran, Tehran (no other locality data); MNHN 1960-611, 2, 127.0-144.0 mm standard length, Tehran, Jaj River east of Tehran (ca. 35º45'N, ca. 51º42'E) USNM 205932, 3, 78.5-159.4 mm standard length, Tehran, stream southwest of Tehran (35º34'N, 51º03'E).

Fish identified as *Capoeta cf. aculeata* (see above from the northern Dasht-e Kavir basin):- CMNFI 2007-0005, 7, 27.8-84.2 mm standard length, Semnan, spring at Nardin (ca. 37º03'N, ca. 55º47'E); CMNFI 2007-0006, 9, 59.9-127.2 mm standard length, North Khorasan, spring in south of Garmeh (ca. 36º58'N, ca. 56º15'E); CMNFI 2007-0007, 8, 59.4-79.3 mm standard length, North Khorasan, stream supplemented by qanats, Kal-e Tangeh (ca. 36º59'N, ca. 56º29'E); CMNFI 2007-0008, 2, 72.1-84.3 mm standard length, North Khorasan, qanat at Jajarm (36º57'N, 56º23'E); CMNFI 2007-0009, 18, 35.9-108.1 mm standard length, Semnan, qanat at Amirabad (ca. 36º31'N, ca. 56º45'E); CMNFI 2007-0010, 11, 80.8-123.1 mm standard length, Razavi Khorasan, qanat at Haresabad (36º07'N, 57º37'E); CMNFI 2007-0011, 12, 34.1-85.4 mm standard length, Razavi Khorasan, Kal-e Shur River south of Neyshabur (36º05'N, 58º43'E).

Fish identified as *Capoeta cf. aculeata* (see above from the western Namak Lake basin):- CMNFI 1979-0458, 2, 90.7-108.4 mm standard length, Qazvin, Khar River 6 km north of Ab-garm (35º47'N, 49º20'E); CMNFI 1979-0462, 5, 37.8-50.9 mm standard length, Markazi, Mazdaqan River (35º06'30"N, 49º40'30"E); CMNFI 1979-0464, 1, 62.7 mm standard length, Markazi, qanat at Kheyrabad (34º08’N, 50º00’E); CMNFI 2007-0076, 12, 37.4-97.4 mm standard length, Markazi, Malekabad qanat east of Arak (34º05'N, 49º53'E); CMNFI 2007-0122, 2, 39.8-45.7 mm standard length, Qazvin, Khar River basin south of Takestan (ca. 35º56'N, ca. 49º30'E).

## ***Capoeta anamisensis***
Zareian, Esmaeili and Freyhof, 2016



*Capoeta anamisensis*, Hormozgan, Rudan River, Hamid Reza Esmaeili.

**Common names.** Siyah mahi Minab.

[Minab scraper].

**Systematics.** *Capoeta anamisensis* is described from Hormuzgan Province, Moradabad River at Ziarat Ali, Minab River drainage, 27º45'47.6"N 57º14'31.8"E. The holotype is in the Zoological Museum of Shiraz University, Collection of Biology Department, Shiraz under ZM-CBSU Z131 and is 144.0 mm standard length. Paratypes are FSJF (Fischsammlung J. Freyhof, Berlin) 3513, 3 fish, 167-187 mm standard length, ZM-CBSU Z126-130, 5, 134-139 mm standard length, ZM-CBSU Z132-134, 3, 147-164 mm standard length, ZM-CBSU Z260 1, 123 mm standard length, all same data as the holotype, and ZM-CBSU C402-403, 2, 91-96 mm standard length, ZM-CBSU C405-411, 7, 62-88 mm standard length, ZM-CBSU C415-416, 2, 54-66 mm standard length, ZM-CBSU C418, 1, 62 mm standard length, ZM-CBSU C422, 1, 55 mm standard length, and ZM-CBSU C426, 1, 101 mm standard length, all from Siaho River at Siaho, Hasan Langi River drainage, 27º45'35.8"N, 56º32'18.7"E.

The species is named for Anamis, the old name for Minab on the Minab River.

**Key characters.** This species is distinguished from other *Capoeta* species by having 56-67 lateral line scales, 11-13 scales between the dorsal fin and the lateral line, total gill rakers 21-25, the body and head without irregular brown to black speckles (except in some young), and a distribution in the Hormuz basin. The mtDNA COI barcode and cytochrome *b* regions also distinguish the species.

**Morphology.** The body is rounded, somewhat compressed and moderately deep. It is deepest just in front of the dorsal fin. The predorsal profile is convex. The caudal peduncle is compressed and relatively deep. The snout is rounded and has a groove in front of the nostrils. The eye overlaps with the rear half of the head. The mouth is small, transverse and almost straight, the lower jaw has a horny sheath and the rostral cap is well-developed, partly overlapping the upper lip. Young have a more u-shaped mouth. The upper lip is moderately thick as is the lower lip at the corners. The posterior barbel is thin and extends back between the nostril and eye levels or to the eye. The last unbranched dorsal fin ray or spine has a soft tip and is serrated along 60-80% of its length with medium-sized, well-separated denticles. The spine is strong. The dorsal fin margin is very slightly rounded and the fin origin is slightly anterior to that of the pelvic fin. The dorsal fin tip reaches back to the anal fin origin level when depressed or falls short. The anal fin margin is straight to rounded and the depressed fin does not reach back to the caudal fin base. The caudal fin is moderately forked with rounded to pointed tips, the lower tip being more rounded than the upper one. The pelvic fin is rounded and may extend almost back to the anus. The pectoral fin is rounded and does not extend back to the pelvic fin.

Dorsal fin with 3-4 unbranched rays and 8-9 branched rays, usually 8, anal fin with 3 unbranched and 5-6 branched rays, usually 5, pectoral fin branched rays 14-16, and pelvic fin branched rays 7-8. Lateral line scales 56-67, scales above the lateral line 11-13, scales below the lateral line 6-8, and caudal peduncle scales 21-24. There is a pelvic axillary lobe. The dorsal and ventral scale margins are short and rounded with posterior margin very elongate and rounded. The anterior margin is rounded to wavy with a rounded central part, indented above and below. The focus is subcentral anterior and circuli are fine. There are moderate numbers of anterior and posterior radii, with a few in the lateral fields. Total gill rakers number 21-25. Pharyngeal teeth are spatulate.

Meristic values are:- dorsal fin branched rays 8(9), anal fin branched rays 5(9), pectoral fin branched rays 14(3), 15(4) or 16(2), pelvic fin branched rays 7(8) or 8(1), lateral line scales 58(2), 59(1), 60(2), 61(-), 62(2), 63(-), 64(1), 65(-), 66(-) or 67(1), scales above the lateral line 12(6) or 13(1), scales below the lateral 7(3) or 8(4), caudal peduncle scales 21(1), 22(1), 23(4)

or 24(1), and total gill rakers 21(2), 22(2), 23(2), 24(2) or 25(1).

**Sexual dimorphism.** Males bear tubercles on the snout, side of the head, flank and caudal peduncle. There are a few small tubercles on the anal fin and the bases of the pectoral, pelvic and caudal fins.

**Colour.** The dorsal and lateral head and the flank are silvery, and the back is pale grey or dark brown. Upper flank scales are outlined by pigment. The flank has a faint, pale yellow stripe along the lateral line. There are no flank spots in adults. The ventral head and body are white. All fins are creamy. The pectoral and pelvic fin bases are orange or yellow and the caudal fin base is dark grey. Dorsal and caudal fin membranes are pigmented while other fins are almost immaculate. The caudal and pectoral fins have some pigmentation on the rays. Young fish are finely spotted on the flanks or have fine melanophores.

**Size.** Attains 18.7 cm standard length.

**Distribution.** This species is found in the Moradabad and Rudan rivers of the Minab River drainage, the Siaho River in the Hasan Langhi River drainage, and the Sar Khun oasis of the Hormuz basin.

**Zoogeography.** This is the south-easternmost species of *Capoeta* in Iran. This species separated from other members of the *C. trutta* species group about 1.83 MYA and is related to *C. trutta* and *C. mandica* in Iran (Zareian *et al*., 2018).

**Habitat.** This species is found in streams, rivers and pools. The two collections below had water temperatures of 21-24ºC (the higher temperature in the oasis on 29 January 1977 as opposed to 20 March 1978), stream width was 4-40 m with an oasis pool 15 m wide, water depth was 5 cm to 1 m, the water was clear to cloudy, current was slow to medium, and algae, reeds and rushes were present.

**Age and growth.** Zareian *et al*. (2018a) gave a *b* value of 2.873 for 15 fish, 6.7-12.3 cm total length.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** Unknown.

**Economic importance.** None.

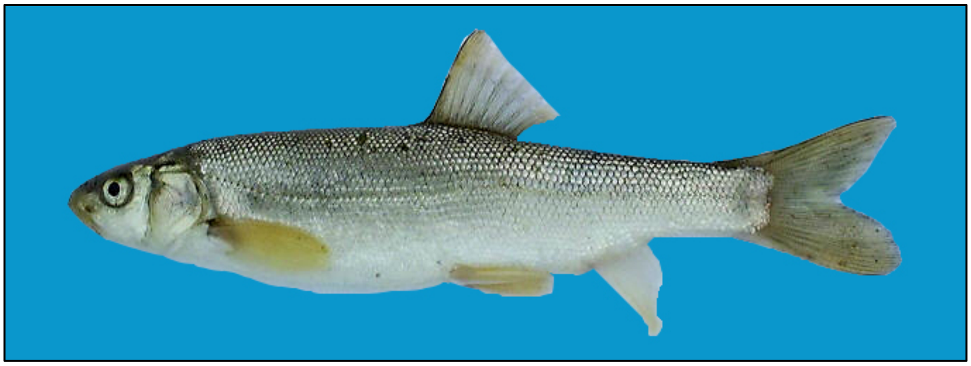
**Experimental studies.** None.

**Conservation**. Described from only a few localities, this species must be considered as rare. Jouladeh-Roudbar *et al*. (2020) listed it as Vulnerable with threats related to habitat loss, degradation due to agricultural pollution, and drought.

**Sources.** Zareian *et al*. (2016).

Iranian material:- CMNFI 1979-0187, 2, 36.9-77.9 mm standard length, Hormozgan, stream and pools at Sar Khun (27º23'30''N, 56º26'E); CMNFI 1979-0411, 7, 42.2-76.5 mm standard length, Hormozgan, Minab River past Rudan (27º24'N, 57º12'E).

***Capoeta buhsei***
Kessler, 1877



*Capoeta buhsei*, Qareh Su, Namak Lake basin, May 2008, Keyvan Abbasi.

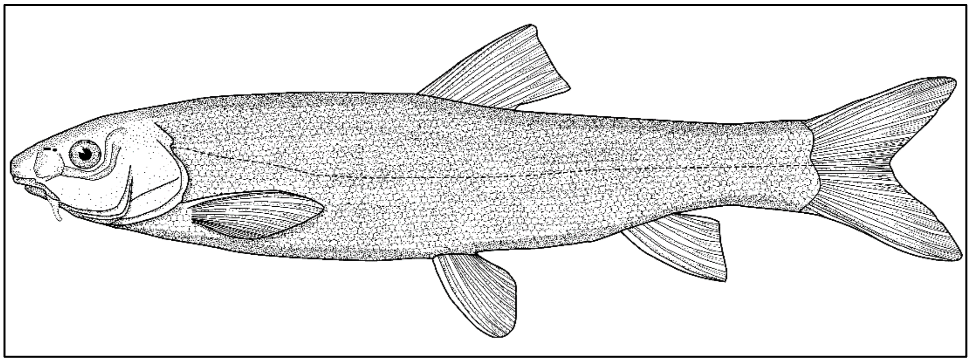
*Capoeta buhsei*, Iran, Dasht-e Kavir basin, Hamid Reza Esmaeili.

*Capoeta buhsei*, Jaj River, Namak Lake basin
(Capoeta buhsei, photographed at Jajrud River …., CC BY-SA 4.0, Arash Aarshan).

**Common names.** Mahi sibili (= moustached fish, from Karaj Lake), shamshiri (= sword-like), siahmahi-ye namaki or siyah mahi Namak (= Namak black fish), siyah fals riz (= tiny scale black fish).

[Black fish, Namak barb, Namak scraper, small scale scraper].

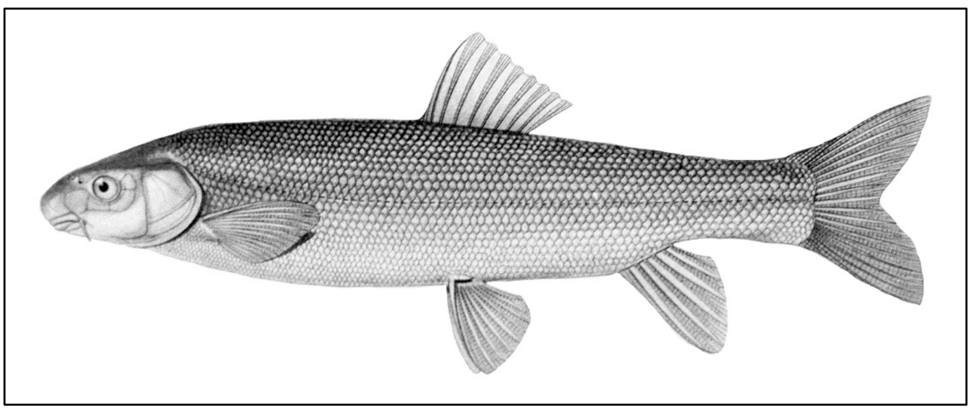
**Systematics.** *Varicorhinus nikolskii* Derzhavin, 1929 described in Latin from the "Keredsh flumen" (= Karaj River near Tehran) is a synonym.



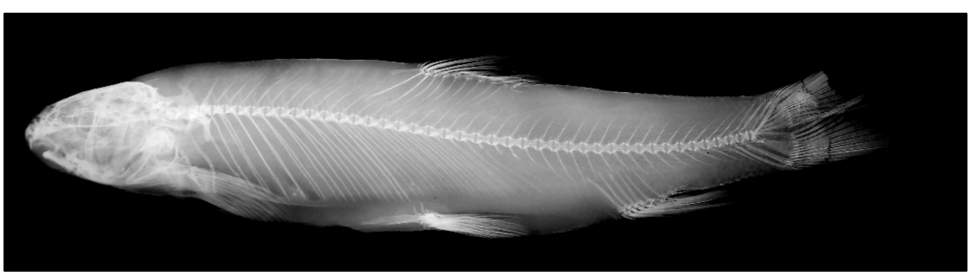
*Varicorhinus nikolskii*, after Derzhavin (1929),
re-drawn by Susan Laurie-Bourque @ Canadian Museum of Nature.

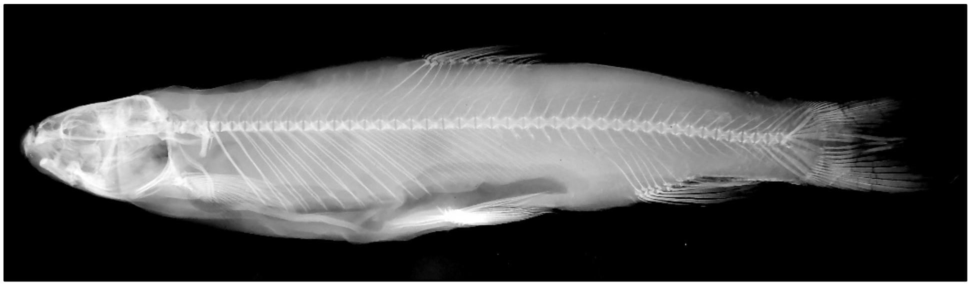
Saadati (1977) placed *Capoeta buhsei* in *Capoeta damascina*, then recognised as a widely occurring species in Iran.

The two syntypes of *Capoeta Buhsei*, 200.7-211.4 mm standard length, are in the Zoological Institute, St. Petersburg (ZISP 2330) and were collected “iz Persii” (= from Persia) by Dr. Buhse in 1849. The 11 syntypes of *Varicorhinus nikolskii* have not been located (Eschmeyer *et al*., 1996).



*Capoeta buhsei*, 25.7 cm total length, syntype, ZISP 2330, vicinity of Tehran,
after Berg (1949).





*Capoeta buhsei*, syntypes, ZISP 2330, vicinity of Tehran,
from Nina G. Bogutskaya, Zoological Institute, St. Petersburg, Brian W. Coad.

**Key characters.** This species is distinguished from other small-scaled *Capoeta* species (61 or more lateral line scales) by having 12-17 scales between the dorsal fin origin and the lateral line, the body and head without irregular brown to black speckles, total gill rakers number 9-19 (usually 15 or less), and a distribution in the Namak Lake and western Dasht-e Kavir basins. Also, the dorsal fin spine is very weak, unserrated or barely serrated in large fish

**Morphology.** The body is rounded and deepest between the end of the pectoral fin and the pelvic fin origin levels. The predorsal profile is gently convex. A nuchal hump develops in larger and well-fed fish. The caudal peduncle is compressed and moderately deep. The snout is rounded and the rear margin of the eye lies in the anterior half of the head. A rostral cap is well-developed, in most fish partly overlapping the upper lip. The subterminal mouth is a large shallow arch with a horny lower edge which may be lost in some preserved fish. Young fish have a more u-shaped mouth. The upper lip is fairly thick and the lower lip corners are particularly fleshy and well-developed. The lower lip is apparent and finely ridged. The upper lip and snout are covered with unculi that occur also over the head but more widely spaced out. The upper lip unculi are densely concentrated and are broader than other head ones. Unculi are also on the lower head surface and belly scales back to the pelvic fins, and on the anal, pectoral and pelvic fin rays and membranes. The posterior barbel is moderately thick and extends back to the anterior pupil or mid-eye level. The dorsal fin spine is weak and denticles are small, present at the base only or extending for about two-thirds of the spine length. Denticles are less extensive in large fish, while proportionally larger and more extensive in the smallest fish. For fish 48.9-174.0 mm standard length extent of dorsal fin spine serrations in spine length was 0.3-0.8, mean 0.6. The distal half of the spine is thin and flexible. The margin of the dorsal fin is straight to concave. The dorsal fin origin lies over that of the pelvic fin or slightly in advance. The depressed dorsal fin does not extend back to the anal fin origin level. The anal fin margin is rounded and the depressed fin does not reach back to the caudal fin base. The caudal fin is shallowly forked with rounded tips, the lower often being very rounded. The pelvic fin is rounded and its tip is remote from the anus. The pectoral fin margin is rounded and its tip does not reach back to the pelvic fin origin.

Dorsal fin unbranched rays 3-5, branched rays 7-9, usually 8, anal fin unbranched rays 3, branched rays 5, pectoral fin branched rays 14-20, and pelvic fin branched rays 7-10 (Zareian and Esmaeili, 2017). Lateral line scales 72-99 and scales above the lateral line 12-17. Scales are found on the back and on the belly. Up to three pelvic axillary scales are present. Scales have parallel dorsal and ventral margins, a rounded posterior margin and an anterior margin with a rounded central protuberance. Radii are on all fields including a few long and curved ones on the lateral fields. The focus is subcentral anterior and circuli are numerous and fine. Total gill rakers number 9-19 in literature suggesting lower counts may be of lower limb

rakers only (but see my total counts below), reaching the second raker below when appressed but only the next raker in small fish. Pharyngeal teeth in the main row are spatulate, the crowns flat, narrow and curved. Tooth counts are usually 2,3,4 or 5-5 or 4,3,2. The fifth tooth in either row is small and variably present. This may be size related although the fish examined here were all relatively small and showed no clear trend. The gut is elongate with several long coils. Total vertebrae number 43-47.

The osteology of this species has been described by Seifi *et al*. (2017) with differences from fish identified as *C. damascina* noted. Jawad and Alwan (2020) gave comparative details of the vertebral column and dorsal, anal and caudal fins in a study of the osteology of the *Capoeta damascina* species complex.

Meristic values are:- dorsal fin branched rays 8(35) or 9(3), anal fin branched rays 5(38), pectoral fin branched rays 14(1), 15(-), 16(-), 17(20), 18(11) or 19(6), pelvic fin branched rays 7(1), 8(5) or 9(31), lateral line scales 72(2), 73(1), 74(-), 75(3), 76(4), 77(2), 78(1), 79(7), 80(4), 81(5), 82(2), 83(2), 84(2), 85(-), 86(2) …. 91(1), total gill rakers 9(2), 10(2), 11(4), 12(12), 13(11), 14(4), 15(2), 16(-) or 17(1), pharyngeal teeth 2,3,4-4,3,2(7), 2,3,4-5,3,2(6), 2,3,5-4,3,2(5), 2,3,5-5,3,2(1), 1,3,4-4,3,2 (1) or 2,3,4-4,3,1(1), and total vertebrae 43(2), 44(23), 45(21), 46(7) or 47(1). The two syntypes have 44 total vertebrae.

Counts from Alwan (2010) and Alwan *et al*. (2016): dorsal fin unbranched rays 4(8) or 5(2), dorsal fin branched rays 8(10), anal fin unbranched rays 3(10), anal fin branched rays 5(7), pectoral fin branched rays 15(2), 16(10), 17(4), 18(6), 19(-) or 20 (2), pelvic fin branched rays 7(2), 8(14) or 9(10), lateral line scales, 72(1), 73(-), 74(3), 75(-), 76(1), 77(2), 78(1), 79(2), 80(-), 81(4), 82(3), 83(1), 84(3), 85(4), 86(1), 87(2), 88(-), 89(1), 90(-), 91(1), 92(-), 93(-), 94(-) or 95(1), scales between dorsal fin origin and lateral line 12(1), 13(6), 14(8), 15(3) or 16(2), scales around caudal peduncle 26(1), 27(3), 28(2), 29(5), 30(5) 31(3), 32(4) or 33(3), lower limb gill rakers 7(1), 8(3), 9(4) or 10(2), total gill rakers 12(10), 13(13) or 14(6), and total vertebrae 44(4). Jawad and Alwan (2020) gave total vertebrae as 40-46, the lower count being low but if it is assumed the four Weberian vertebrae were omitted then this would make the range 44-50 and the upper count would then be high.

**Sexual dimorphism.** One male specimen, measuring 94.6 mm standard length (CMNFI 1979-0458, 9 July 1978) had large tubercles on anal fin rays, fine tubercles scattered on the head, on the back and upper flanks one tubercle per scale at the scale centre but not on every scale, all along the lateral line at one tubercle per scale, and below the lateral line only in the area above the anal fin.

**Colour.** Overall colour is a light silvery-golden or brownish, darker on the back and lighter below the lateral line. The fins are opaque or whitish, with or without a grey tinge. The pectoral fin may be golden (Alwan, 2010). Pectoral and pelvic fins are yellow to brown and darker than the anal fin. Overall colour is brownish to grey in preservative without spots or any distinctive markings. The back is dark. The peritoneum is dark brown to black in preserved fish.

**Size.** Reaches 27.0 cm and 356 g (Bagheri *et al*., 2017).

**Distribution.** This species was known as an endemic of the Namak Lake basin in Iran but is also now known from Dasht-e Kavir and possibly other basins. In the Dasht-e Kavir basin from Hableh, Nam and Qolrudbar rivers and at Boneh Koh (= Bon-e Kuh) in the western Dasht-e Kavir basin immediately adjacent to the Namak Lake basin; and in the Namak Lake basin from the Ab Chay, Abhar, Abshine, Afgah, Bahadorbaik (= Bahador Beyg), Bar, Eberu-Simin, Jaj, Kaleh, Kan, Karaj, Ken, Khanigan, Khar, Kharm Khosbijan, Khomeigan, Kordan,

Mazdaghan, Pol-e Doab, Qareh Chay or Qareh Su, Qom, Ravan, Rudbar, Salehbad, Sharrah, Siah, Sinak, Soleghan, Taghra, Yokhari and Zehtaran rivers, Cheshmeh (= Spring) Emarat and in the 15 Khordad and Karaj dams (Derzhavin, 1929; Wossughi, 1978; Abdoli, 2000; Touraji and Vosoughi, 2006; Abbasi, 2009; Mirzaei *et al*., 2010; Levin *et al*., 2012; Hashemzadeh Segherloo and Abdoli, 2015; Tabatabaei *et al*., 2015; Alwan, 2010; Jouladeh-Roudbar *et al*., 2015, 2017; Alwan *et al*., 2016, 2016; Ghanavi *et al*., 2016; Abbasi *et al*., 2017; Bagheri *et al*., 2017; Seifi *et al*., 2017; Zareian and Esmaeili, 2017; Nasrolah Pourmoghadam *et al*., 2019). Recorded from the Mazdaghan River, Namak Lake basin by Touraji and Vosoughi (2006), presumably the species they identified as *C. barroisi* or *C. sieboldi*.

General records from the Kerman-Na'in and possibly Sirjan basins need confirmation (Jouladeh Roudbar *et al*., 2015; Zareian and Esmaeili, 2017). Hashemzadeh Segherloo and Abdoli (2015) recorded *C. buhsei* haplotypes in the Karun River basin, indicating an interconnection of the Namak Lake and Tigris River basins (and see Alwan *et al*. (2016) where *C. buhsei* and *C. coadi* of these basins are sister species).

Also found in Chitgar Lake, an artificial water body in northwest Tehran (Bagheri *et al*., 2016; Ramin *et al*., 2016; Abbasi *et al*., 2017; Ramin and Doustdar, 2017b; Ramin *et al*., 2018).

Abdoli (2000) questionably maps it from the Esfahan basin and Moghadamnia *et al*. (2015a, 2015b) reported on fish from the Zayandeh River. A report from Lake Zaribar, Kordestan (*Abzeeyan*, Tehran, 5(5):III, 1994) is presumably a mis-identification and records from springs of Kul River basin near Darab in the Hormuz basin (Bianco and Banarescu (1982) and the Hamun-e Jaz Murian basin (Vossoughi, 1998) are also very questionable.

**Zoogeography.** An endemic of an interior Iranian basin, its zoogeographical relationships to other *Capoeta* are summarised above under the genus. Zareian *et al*. (2018) placed this species in the *C. damascina* species group of *Capoeta* where it separated from *C. coadi* 2.69 MYA and, with *C. coadi* and *C. saadii*, from other members 4.24 MYA.

**Habitat.** This species is found in rivers, streams, lakes, dams, springs and qanats. Collection data included a temperature range of 14-22ºC, pH 6.05-7.2, conductivity 0.45-4.0 mS, river width 0.5-7.0 m, slow to fast current, capture depth 40-70 cm, clear to muddy water, detritus, mud, sand, gravel, pebble or stone bottoms, submergent and encrusting vegetation, and a grassy or forested shore. Narjes Tabatabaei *et al*. (2014) found depth, undercut banks, pools, boulders, overhanging vegetation, instream vegetation and canopy had a direct relationship with this species' distribution at 66 stations in the Kordan River. The presence of cobble had a negative relationship. Dolatpour *et al*. (2016) studied habitat preferences of fish identified as *C. damascina* in the Kordan River using the habitat suitability index finding a downstream habitat was the most suitable. Eagderi *et al*. (2016) found that fish in the Jaj River selected habitats with low elevation, width and flow velocity, with larger stones diameter in the substrate, high temperature, neutral pH, and high conductivity and total dissolved solids, indicating the Jaj River was a suitable habitat for this species. Ahmadzadeh *et al*. (2019) measured nine environmental factors in the Jajrud (= Jaj River), namely pH, temperature, electrical conductivity, total dissolved solids, dissolved oxygen, depth and width of the river, water current velocity, and diameter of the substrate stones. This species preferred habitats with fast water current, deep and wide areas of the river with low temperature, and a substrate of large stones. The first station (upstream), with a habitat suitability index of 0.796, was the most suitable habitat. Yousefi *et al*. (2019b) used a species distribution model to assess the

effects of climate change on this species and found that it would lose nearly 58% of its favourable habitat by the year 2070.

Habitat of *Capoeta buhsei*, Alborz, Kordan River, Yazdan Keivany.

**Age and growth.** Esmaeili *et al*. (2014) gave a *b* value for 30 fish from the Namak Lake basin, 14.0-24.0 cm total length, as 2.74. Narjes Tababtabei *et al*. (2014) gave the length-weight relationship for 132 fish, mean length 14.84 cm, from the Kordan River as $W = 0.01L^{2.87}$ and the mean condition factor as 0.86. Tabatabaei *et al*. (2015) gave a *b* value of 2.78 for 132 fish, 3.84-25.39 cm total length, from the Kordan River (note change in *b* value). Bagheri *et al*. (2017) found fish from the Kan River, Tehran to be $0^+$ to 7 years old. Yazdani *et al*. (2016, 2019) examined 92 fish, 64.7-222.4 mm total length, from the Gharachay (= Qareh Chay) River, Saveh and found fish up to 4 years old with males reaching a mean of 131.5 mm standard length and females 153.0 mm, a female:male sex ratio of 0.73:1, and length-weight relationships $W = 35.55TL^{3.2}$ in males and $W = 14.8TL^{3.07}$ in females, positive allometric growth.

**Food.** Gut contents include aquatic insect larvae and masses of filamentous algae, suggesting that aufwuchs is an important diet item. Dolatpour *et al*. (2014) recorded a relative gut length of 2.2 indicating herbivory and a condition factor of 1.37 in fish identified as *C. damascina* from the Kordan River. Bagheri *et al*. (2017) gave the diet as benthos in the Kan River, Tehran.

**Reproduction.** Fish caught on 5 June 1990 (CMNFI 1993-0152) measuring 121.3-132.6 mm standard length had small eggs, perhaps because this size of fish was not mature. A 174.0 mm standard length fish caught in January 1970 (CMNFI 1979-0094) had larger eggs than those from the June fish. A male fish caught on 5 May 1989 and measuring 146.4 mm standard length had mature testes (CMNFI 1993-0151). Strongly tuberculate fish were caught on 9 July 1978 (CMNFI 1979-0458 - see above). Dolatpour *et al*. (2014) found the highest gonadosomatic in fish identified as *C. damascina* from the Kordan River occurred in late winter. Yazdani *et al*. (2019) found Gharachay (= Qareh Chay) River, Saveh fish had a mean egg diameter of 0.87 mm with a range of 0.67-1.1 mm, a mean absolute fecundity of 4,917.2 eggs and relative fecundity of 69.1 eggs/g body weight. The highest gonadosomatic index for females was in January and spawning was first observed in August.

**Parasites and predators.** Molnár and Jalali (1992) recorded the monogenean *Dactylogyrus pulcher* from fish in the Jajrud (= Jaj River) identified as *C. capoeta* which may have been *C. buhsei* or *C. aculeata*. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Pallisentis cholodkowskyi* in fish from the 15 Khordad Dam.

**Economic importance.** None.

**Experimental studies.** Safavi *et al*. (2015) looked at the effect of cypermethrin on fish identified as *C. damascina* from the Kordan River in the Namak Lake basin and found injuries to gill tissue increased with concentration and exposure time to the insecticide. Safavi *et al*. (2016) found also that sub-acute concentrations of the insecticide cypermethrin had negative effects on haematological parameters. Shahbazi *et al*. (2015) found extensive behavioural and haematological effects of the insecticide malathion on fish identified as *C. damascina* from the Kordan River, suggesting that the blood levels could be used as a bioindicator in flowing waters. Poorbagher *et al*. (2016) used multivariate methods to analyse the effects of the pesticide diazinon on the liver of fish from the Kordan River, showing significant effects of concentration and exposure time on manifestation of histopathological symptoms.

**Conservation.** Listed as of Least Concern by the IUCN (2015).

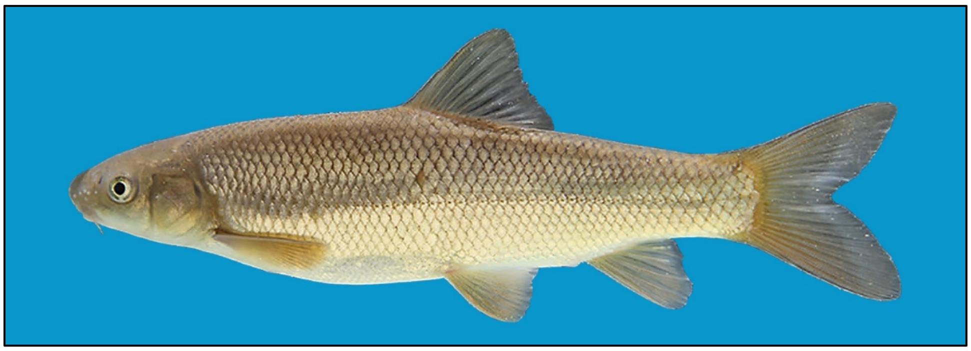
**Sources.** Type material:- *Capoeta buhsei* (ZISP 2330).

Iranian material:- CMNFI 1970-0588, 19, 42.4-128.9 mm standard length, Alborz, Karaj Lake (35º57'N, 51º06'E); CMNFI 1979-0094, 2, 143.1-174.0 mm standard length, Alborz, Karaj Lake (35º57'N, 51º06'E); CMNFI 1979-0255, 5, 40.3-54.2 mm standard length, Markazi, Bar River drainage 2 km west of Shahabiyeh (33º51'30"N, 50º23'E); CMNFI 1979-0266, 2, 52.4-54.3 mm standard length, Esfahan, spring at Nowqan (ca. 33º10'N, ca. 50º05'E); CMNFI 1979-0458, 1, 94.2 mm standard length, Qazvin, Khar River 6 km north of Ab-garm (35º47'N, 49º20'E); CMNFI 1979-0459, 2, 27.0-31.6 mm standard length, Hamadan, stream 2 km south of Razan (35º22'N, 49º02'E); CMNFI 1979-0461, 1, 54.1 mm standard length, Hamadan, qanat at Taveh (35º07'N, 49º02'E); CMNFI 1979-0462, 9, 33.7-44.8 mm standard length, Markazi, Mazdaqan River (35º06'30"N, 49º40'30"E); CMNFI 1979-0495, 1, 42.5 mm standard length, Markazi, Nam River west of Firuz Kuh (35º43'N, 52º40'E); CMNFI 1980-0154, 71, 12.0-34.9 mm standard length, Alborz, Karaj River below village (35º47'N, 50º58'E); CMNFI 1980-0156, 27, 32.4-54.3 mm standard length, Alborz, Karaj River below village (35º47'N, 50º58'E); CMNFI 1993-0151, 1, 146.4 mm standard length, Markazi, Sharra River near Far (34º03'N, 49º19'E); CMNFI 1993-0152, 2, 121.3-132.6 mm standard length, Markazi, Sharra River near Khosbijan (34º07'N, 49º23'E); CMNFI 1993-0153, 2, 104.3-138.9 mm standard length, Markazi, Sharra River near Emarat (33º52'N, 49º36'E); CMNFI 1993-0154, 1, 124.0 mm standard length, Markazi, Sharra River near Far (34º03'N, 49º20'E); CMNFI 2007-0074, 3, 30.9-89.2 mm standard length, Markazi, Qareh Chay 32 km west of Arak (34°03´N, 49°21´E); CMNFI 2007-0078, 5, 92.1-43.4 mm standard length, Markazi, Qom River (ca. 34º18'N, ca. 50º32'E); CMNFI 2007-0079, 14, 24.5-33.5 mm standard length, Zanjan, Abhar River basin (ca. 36º16'N, ca. 49º08'E); CMNFI 2007-0120, 1, 36.1 mm standard length, Hamadan, Ab Chay (ca. 34º49'N, ca. 48º29'E); CMNFI 2007-0121, 3, 82.5-141.5 mm standard length, Hamadan, Qareh Su basin north of Razan (ca. 35º25'N, ca. 49º02'E); CMNFI 2007-0122, 1, 41.7 mm standard length, Qazvin, Khar River basin south of Takestan (ca. 35º56'N, ca. 49º30'E); ZMH 2632, 1, 148.2 mm standard length, Dojodje (no other locality data).

*Capoeta cf. buhsei*:- CMNFI 1993-0154, 1, 99.9 mm standard length, Markazi, Sharra River near Far (34º03'N, 49º20'E).

***Capoeta capoeta***
(Güldenstädt, 1773)

*Capoeta capoeta*, Iran, Simineh River, Lake Urmia basin, Hamid Reza Esmaeili.



*Capoeta capoeta*, Iran, Baranduz River, Lake Urmia basin, Hamid Reza Esmaeili.

*Capoeta capoeta*, East Azarbayjan, Ghalechai (= Qal'eh River),
Lake Urmia basin, October 2011, Keyvan Abbasi.

*Capoeta capoeta*, East Azarbayjan, Ghale Chay River (= Qal'eh River), Lake Urmia basin, after Jouladeh-Roudbar *et al*. (2017).

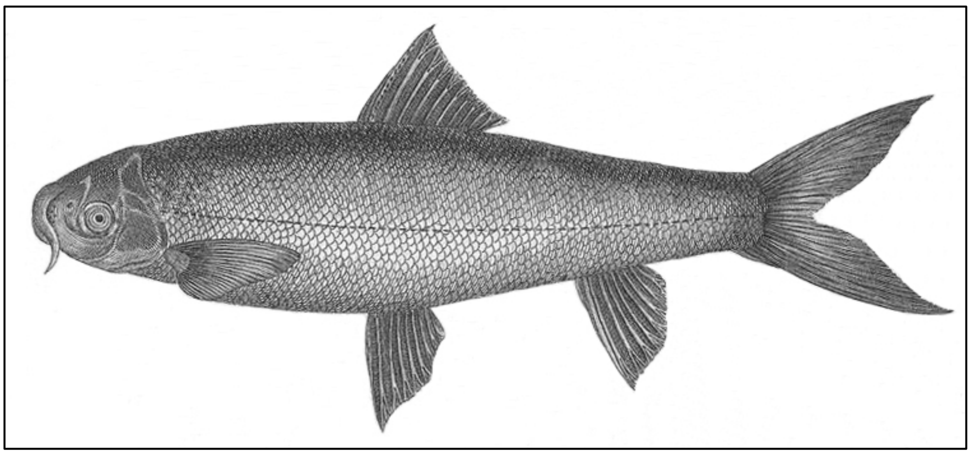
*Capoeta capoeta*, 110.0 mm standard length, ventral head, East Azarbayjan, Ghale Chay River (= Qal'eh River), Lake Urmia basin, after Jouladeh-Roudbar *et al*. (2017).

Dorsal fin spines: *Capoeta capoeta* above (121.0 mm standard length, East Azarbayjan, Ghale Chay River (= Qal'eh River), Lake Urmia basin) and *Capoeta razii* below (116.0 mm standard length), after Jouladeh-Roudbar *et al*. (2017).

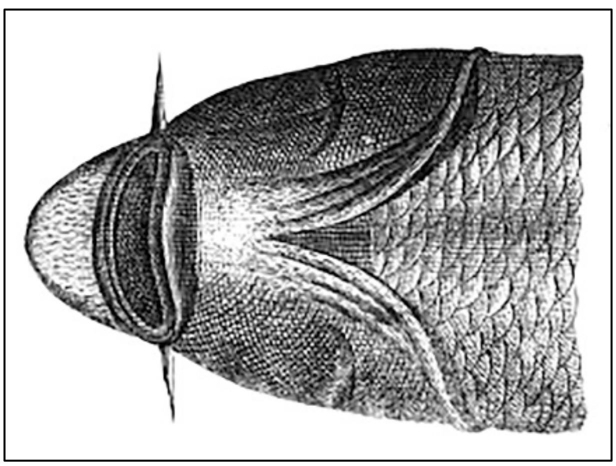
**Common names**. Sang lisak (= ? rock snail), siah mahi (= black fish), siyah mahi ghafghazi (= Caucasian black fish), siahmahi-ye mamoli (= common black fish), tilkhos and teilehkhus.

[Gara balig and Kur xramulyasi, in Azerbaijan; khramulya, capoeta, kapuit, kaput (all apparently derived from local names in Georgia and Armenia, namely khramuli and kapweti); Kurinskaya khramulya or Kura khramulya, Zakaspiiskaya khramulya or Transcaspian khramulya (also marinka is used locally for the Transcaspian khramulya subspecies but this is an error), Araksinskaya khramulya or Aras khramulya, all in Russian; Kafkasya sirazı, Siraz balığı, aptalca in Turkish (Kaya *et al*., 2020; Çiçek *et al*., 2020); Transcaucasian barb; Caucasian scraper; khramulia].

**Systematics.** *Cyprinus capoeta* was originally described from Tbilisi, Georgia, no types are known. Synonyms are *Cyprinus fundulus* Güldenstädt, 1787 from the Caspian Sea, Cyrus River (and *Capoeta fundulus* Valenciennes, 1842, perhaps just a new combination, according to the *Catalog of Fishes*, downloaded 26 April 2020), *Capoeta Hohenackeri* Kessler, 1877 from Caucasia (probably lower Kura and Aras rivers, Azerbaijan (holotype ZISP 2864)), and *Varicorhinus capoëta araxensis* Dadikyan, 1986 described from the Aras River in Armenia with no types are known.



*Cyprinus capoeta*, syntype, after Güldenstädt (1773).



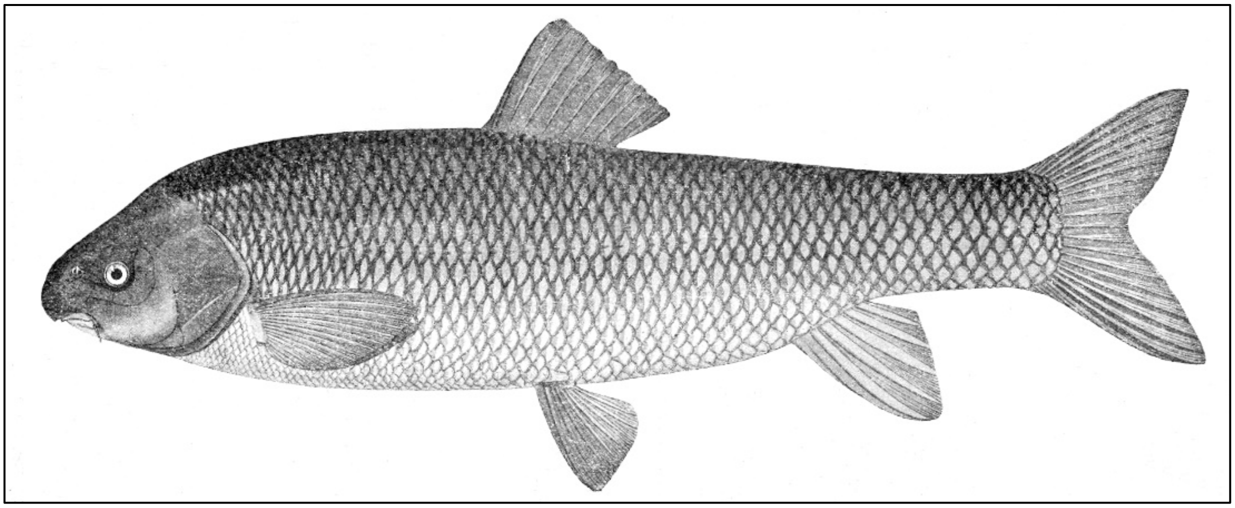
*Cyprinus capoeta*, ventral head of syntype,
after Güldenstädt (1773).

*Capöeta Guldenstädtii* De Filippi in Tortonese, 1940 from “F. Arasse, Erzerum (Anatolia)” is *Capoeta capoeta* but it is an unneeded new name (Tortonese, 1940; Eschmeyer *et al*., 1966); two syntypes are in the Istituto e Museo di Zoologia della R. Università di Torino (MZUT N.729).

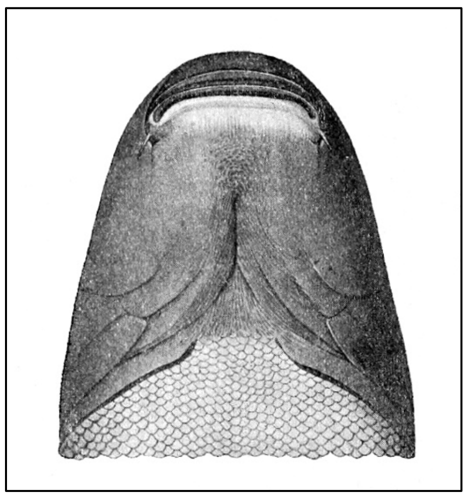
*Capoeta hohenackeri* Kessler, 1877 described from tributaries of the Kura and Aras rivers has a high lateral line scale count in the original description (78) and might be a mislabelled *Capoeta tinca* (Heckel, 1843) from Black Sea drainages of Georgia and Turkey rather than the Caspian Sea basin.

*Capoeta capoeta gracilis* was the subspecies recognised for much of Iran in the literature and *Capoeta capoeta heratensis* was the subspecies from the Tedzhen (= Hari) River basin (Berg, 1949). The former usually has one pair of barbels, the latter two pairs (but see below). Bianco and Banarescu (1982) limited *C. c. gracilis* to basins between the Sefid River and the Atrak while *C. c. capoeta* was found in the Kura-Aras basin. Holčík and Jedlička (1994) considered that the two subspecies *gracilis* and *heratensis* did not exist but that the taxon *C. capoeta* exhibits clinal variation. *Capoeta gracilis* and *C. heratensis* are now recognised as distinct species outside the Caspian Sea basin.

Bănărescu in Bănărescu (1999) limited *C. capoeta gracilis* to the Lake Urmia basin and the Sefid River in Iran (and the lower Kura River of Azerbaijan) while his *C. capoeta* aff. *gracilis* (an unnamed subspecies related to *C. capoeta gracilis*) was found along the rest of the Iranian Caspian shore. However, his material was limited (and did not include any from Esfahan, the type locality of *gracilis*) and the analysis was based on lateral line scale counts only. Bănărescu in Bănărescu (1999) also stated that *C. capoeta sevangi* De Filippi, 1865 is the subspecies of the Araxes (= Aras) River basin, presumably including Iran, distinguished from the type subspecies, *C. capoeta capoeta* of the Kura River basin, by having the dorsal fin margin straight or slightly convex as opposed to slightly to moderately notched. This character does not seem to be significant for such wide ranging and variable populations, which he admitted in one case at least (Kura River at Mingechaur), showed differences between samples from the same locality at different times. Jouladeh-Roudbar *et al*. (2020) noted that Zareian *et al*. (2017) unjustifiably considered *Capoeta sevangi* De Filippi, 1865 a full species found, in Iran, in the Aras River basin of the Caspian Sea and the Lake Urmia basin (formerly identified there as *C. capoeta*). However, Ghanavi *et al*. (2016), using the cytochrome *b* genetic marker, found *C. sevangi* from Lake Sevan, Armenia (the type locality) nested within *C. capoeta* samples from the Arpa and Aras rivers of Azerbaijan and differed with less than 0.4% genetic distance. Additionally, Jouladeh-Roudbar *et al*. (2020) could not separate *C. sevangi* and *C. capoeta* using morphological characters suggested by Zareian *et al*. (2017). C. *sevangi* was synonymised with *C. capoeta* as suggested too by earlier authors. Kuljanishvili *et al*. (2020) concurred.



*Capoeta sevangi*, 50.5 cm total length, ZISP 8631, Armenia, Lake Sevan, after Berg (1916).



*Capoeta sevangi* mouth, as above.

Abdurakhmanov (1962) compared fish from the Kura River basin (presumably *C. c. capoeta*) with fish from the Lenkoranchai and Bilyashchai in Azerbaijan (*C. c. gracilis*, now *C. razii*) and found that the latter had fewer dorsal fin rays on average, greater head length and depth, smaller eye, longer snout and postorbital distance, greater body depth and caudal peduncle depth, a shorter postdorsal distance, a shorter dorsal fin base, lesser dorsal fin height, a longer anal fin base, a greater pectoral-pelvic distance, and a shorter pelvic-anal fin distance.

Records of *Capoeta capoeta* from the Tigris River basin were considered to be probably *Capoeta damascina* with low scale counts (F. Krupp, *in litt*., 1986), and now are presumably one of the new species recently described.

Wossughi (1978) described, in a dissertation, a subspecies of *C. capoeta* namely "*araquica*" from the Namak Lake basin (from "Tschmeh Jafar Abad bei Araq") but this work may not be published in the sense of the International Code of Zoological Nomenclature (Ride *et al*., 1985). In any case, the holotype is *Capoeta aculeata* and the other material comprises 21 *Leuciscus cephalus* (= *Squalius namak*) and four *Capoeta aculeata* (F. Krupp, *in litt*., 1984). The type material, all female, is stored in the Zoologischen Instituts und Zoologischen

Museums der Universität Hamburg (holotype, 132 mm standard length under ZMH 5946, and two paratypes, 115-121 mm standard length, under ZMH 5947).

Radkhah *et al*. (2016) compared fish in the up and downstream parts of the Zarrineh River in the Lake Urmia basin and found no differences in meristic characters but significant differences in morphometric characters, although these were not sufficient to separate the populations. Differences were attributed to ecological conditions such as flow rate, temperature, oxygen, vegetation and nutritional status. Keivany *et al*. (2019) carried out a morphometric comparison of 713 fish from 32 rivers in the Caspian Sea, Lake Urmia and Hari river basins, all identified as *C. capoeta* (the Hari River fish are now identified as *C. heratensis*). The Hari River population was fully separated from the Lake Urmia populations. Caspian Sea populations overlapped with both other populations. A cluster analysis grouped the populations into Hari River and Caspian Sea populations in one group and Lake Urmia population in another. This demonstrates the limits of morphometry in distinguishing species now defined by molecular data.

**Key characters.** This species is distinguished from other *Capoeta* species by having 46-70 lateral line scales, 7-11 scales between the dorsal fin and the lateral line, the body and head without irregular brown to black speckles, and a distribution in the Caspian Sea (Aras River basin) and Lake Urmia basins.

Berg (1948-1949) and Abdurakhmanov (1962) separated *C. c. capoeta* from *C. capoeta gracilis* by the following key:-

1(2). Dorsal fin emarginate above; lateral line scales usually 55-59; dorsal fin spine strong with numerous denticles; back behind occiput and particularly in front of the dorsal fin strongly compressed = *C. c. capoeta*

2(1). Dorsal fin truncated in adults; lateral line scales usually 47-58; dorsal fin weak; back behind occiput not or only weakly compressed; radii on scales with minute recesses = *C. c. gracilis* (*sic*, presumably *C. razii*)

**Morphology.** The body is rounded and deepest in front of, or at the dorsal fin origin. The dorsal profile in front of the dorsal fin is convex to almost straight and may fall steeply to the head. The caudal peduncle is compressed and moderately deep. The snout is short and rounded and overlaps the upper lip. The eye is well in the anterior half of the head. The mouth is ventral, u-shaped in young and a shallow arch with a horny edge in adults. The upper lip is thin and the lower is only developed in the corners of the mouth. Barbels are thin to moderate in size. The posterior barbel is short and extends to mid-pupil or falls short of the anterior eye margin. Barbels in small specimens extend almost as far as the posterior margin of eye and in large specimens only to the anterior margin of the eye. The dorsal fin spine is moderate with small denticles which may extend almost to the spine tip. Denticles may be completely lacking. The dorsal fin margin is emarginate and its origin lies well anterior to the level of the pelvic fin origin. The depressed dorsal fin does not extend back to the anal fin origin level. The anal fin margin is rounded to straight and the fin extends back almost to, or clearly short of, the caudal fin base when depressed. The caudal fin is moderately forked with a pointed dorsal tip and a rounded ventral tip. The pelvic fin margin is rounded and the fin does not reach back the anal fin origin. The pectoral fin margin is rounded to emarginate and the fin does not extend back to the pelvic fin origin.

Günther (1899) pointed out that this species shows considerable morphological variation, even in fish caught at the same place and time. The mouth can vary from straight to a gentle crescent to a distinct crescent, e.g., in three fish from the Nazlu Chay. There are also

variations in dorsal fin spine development and the crown of the head can be flattened or convex. Berg (1948-1949) also indicated that the various subspecies are very close to each other and that their distributions are not clearly isolated.

Dorsal fin unbranched rays 3-5, modally 4, branched rays 6-10, usually 8-9, anal fin unbranched rays 2-4, usually 3, branched rays 5, pectoral fin branched rays 15-23, modally 19 or 20, and pelvic fin branched rays 7-11, modally 9 (mode 10 in Turan *et al*. (2006)). Lateral line scales 46-70 (54-65 in Zareian *et al*. (2018), 49-59 in Schöter *et al*. (2009), 54-59 in Turan *et al*. (2006)). Scales between dorsal fin origin and lateral line 7-11, usually 8-9, and scales between anal fin origin and lateral line 6-9, modally 7, and caudal peduncle scales 8-11, modally 11 (presumably for only half of the caudal peduncle and excluding one or two lateral line scales). Scales are regularly arranged over the body. There is a pelvic axillary scale and there may be several overlapping scales. Scales have gently convex dorsal and ventral margins, a rounded posterior margin, an anterior margin heavily indented on each side of the rounded centre, moderate numbers of circuli, relatively few radii on the anterior and posterior fields and rarely on the lateral fields, and a subcentral anterior focus. Gill rakers number 16-32, reaching the second raker below when appressed. Lower counts may refer to lower arm rakers only and total counts in the range 21-30 are probably more typical (21-26 in Turan *et al*. (2006)). Pharyngeal teeth are 2,3,4-4,3,2 or 2,3,5-4,3,2 with a hooked tip, spatulate below on posterior teeth while anterior teeth are conical. The gut is elongate with several long coils, 11-12 times the body length for fish 44.0 cm standard length (Berg, 1948-1949). Total vertebrae number 42-48, with the lower counts probably lacking the four Weberian vertebrae. Levin *et al*. (2005) found *C*. *gracilis* (presumably *C*. *razii* now) and *heratensis* (and *steindachneri*) to be oligovertebrate with 41-45 vertebrae, modes 42 to 44, compared to the multivertebrate type subspecies *capoeta* and *sevangi* with 45-48 vertebrae, mode 46 (and see below). Morphometry and longevity also differ between these two groups and it was assumed they belong to different phyletic lines.

The Lake Sevan, Armenia subspecies (*C*. *c*. *sevangi*, now recognised as a distinct species related to *C*. *capoeta*) has 2n = 150 and is closer to “Barbus” than to African *Varicorhinus*, a genus in which Southwest Asian *Capoeta* were once placed (Krysanov, 1999).

Meristic values for Iranian specimens are:- dorsal fin branched rays 7(1), 8(28), 9(-) or 10(1), anal fin branched rays 5(30), pectoral fin branched rays 18(1), 19(9), 20(13), 21(4), 22(2) or 23(1), pelvic fin branched rays 8(2), 9(24) or 10(4), lateral line scales 50(1), 51(2), 52(5), 53(7), 54(10) 55(1) or 56(4), total gill rakers 21(5), 22(7), 23(4), 24(4), 25(6), 26(3), 27(-) or 28(1), pharyngeal teeth 1,3,5-5,3,1(1), 2,3,4-4,3,2(2), or 2,3,4-4,3,3(1), and total vertebrae 46(11), 47(14) or 48(1).

**Sexual dimorphism.** The snout in males may have 2-4 distinct rows of tubercles. In a fish 125.4 mm standard length (CMNFI 1970-0559, caught on 27 June1962), up to four very fine tubercles are present on each back scale predorsally, with fewer on flank scales. A few large tubercles are present on anal fin branched rays 3 and 4. See also photograph above. Abdurakhmanov (1962) reported that caudal peduncle length and lower caudal lobe length are longer in males while anal fin height, pelvic-anal fin distance, postorbital distance and interorbital width are greater in females.

**Colour.** The back is dark grey or green to dark brownish and the flanks light, silvery, silvery-grey, brownish-grey or yellowish. There may be several large black spots or blotches on the flank. The area above the lateral line can be quite dark. The top of the head is darkly pigmented. The belly and lower head surface are pearly-white or silvery to dirty yellow. The

lower head surface and the operculum may be a dirty golden or orange colour with a reddish tint and black dots. Scales are darkly pigmented and are outlined by pigment. Some fish have darker pigment on the skin near the base of the exposed scale forming a spot. One or more parallel lines above the lateral line are present, best developed anteriorly. The pores of the lateral line scales are distinctly dark or with a bright color. The operculum has a broad, yellow-gold spot. The iris is silvery, somewhat darker or yellow-golden above, or golden overall with traces of grey. The front of the dorsal fin and the margin of the caudal fin are black, and the rest of these fins are dark grey, yellowish-grey or dirty yellow or golden with some pink. The black margin to the caudal fin may be best developed on the upper and lower lobes compared to the posterior margin. The distal part of the caudal fin may be lighter than the proximal part. The pectoral, pelvic and anal fins are grey with some pink, yellow or dirty orange and often with a reddish tint, or may be an overall pale pinkish, and have a row of pigment on some first rays. All fins may be dark or mostly translucent. The peritoneum is black. Juveniles have spots and blotches irregularly arranged on the flank with a diffuse caudal spot in some fish.

**Size.** This species reaches 43.0 cm in the Aras River basin of Iran (A. Abdoli, pers. comm., 1995) and 43.5 cm fork length and 1.23 kg in Çıır Lake, Turkey as *C. capoeta capoeta*. May exceed 2.5 kg (Berg, 1948-1949).

**Distribution.** This species is found in the western Caspian Sea basin in the Kura-Aras basin (the Aras River and tributaries in Iran) and in the Lake Urmia basin. In the Caspian Sea basin in the Agh, Ahar, Aras, Balekhlu, Ghotor, Kargan, Qaranqu, Qareh Su, Qotur, Zangbar and Zilber rivers and Aras, Khoda Afarin, Maku and Sattarkhan dams; and in the Lake Urmia basin in the Aji (= Talkheh), Avan, Baranduz, Bardsour, Bitas, Chamalton, Gedar, Ghale Chay (= Qal'eh River), Hasanlu, Kar, Mahabad, Mamiyand, Mardogh, Nazlu, Qader, Qasemlu, Qotur, Saqqez, Shahr, Simineh, Sufi, Tajar, Zarrineh and Zowla rivers and the Aras, Cheragveis, Ghalehchai (= Qal'eh), Hasanlu, Mahabad, Maku and Shaharchay dams, and Marmisho Lake west of Urmia (Günther, 1899; Abdi, 1999; www.mondialvet99.com, downloaded 31 May 2000; Abdoli, 2000; K. Abbasi, see photograph above, 2011; Mirhasheminasab and Pazooki, 2003; Abbasi *et al*., 2005; Masoumian, 2007; Barzegar and Jalali, 2009; Hajirostamloo, 2009; Shiri *et al*., 2009; Rasouli *et al*., 2011; Banan Khojasteh *et al*., 2012; Ramin *et al*., 2012; Hosseinifard *et al*., 2014; Moradi and Eagderi, 2014; Ghasemi *et al*., 2015; Ghanavi *et al*., 2016; Jouladeh Roudbar *et al*., 2016, 2017, 2020; Keivany and Zamani-Faradonbeh, 2016; Radkhah *et al*., 2016; Zareh Reshquoeeieh *et al*., 2016; Dadai Ghandi *et al*., 2017; Eagderi and Moradi, 2017; Rasouli *et al*., 2017; Fathi and Ahmadifard, 2019).

Jouladeh-Roudbar *et al*. (2017) identified fish from the Ghale Chay (= Qal'eh River), Lake Urmia basin as *C. capoeta* but the location number on the map (Figure 1: 16) is transposed and should read 15 to agree with Table 1. Jouladeh-Roudbar *et al*. (2020) mapped this species from the Lenkoran in Iran, in the western Caspian Sea basin.

**Zoogeography.** See above under the genus.

**Habitat.** This species is found in rivers, streams, lakes, dams, lagoons, ponds, marshes, springs, qanats and brackish environments. Günther (1899) found that *Capoeta capoeta* placed in saline Lake Urmia water died in 3.5 minutes. Abbasi *et al*. (2005) stated this is the most abundant fish species in the Mahabad River of the Lake Urmia basin. Ghasemi and Mustafayev (2008) found this species in the Aras River was the most dispersed and had the highest frequency (56.6%) of 17 species collected. My fish have been collected at 16.5-26.0°C in fast water over clay, sand and pebbles.

**Age and growth.** Günther (1899) reported on a male fish from Ula on the Zowla River in the Lake Urmia basin which was only 12.5 cm long yet a sexually mature male, perhaps an instance of a dwarf form.

Maku Dam in West Azarbayjan in the Aras River basin has an estimated 9.4-10.7 tonnes of this species with a maximum sustainable yield of 4.5-4.8 t (Saiad Bourani and Ghaninejad, 2004). Average length of this population was 23.9 cm, weight was 1,626.8 g and age was 2.6 years. Most fish were $3^+$ years old and $5^+$ fish were at a minimum. Infinite length and the growth coefficient were computed as 35.6 cm and 0.39 per year. Total mortality was 0.74, natural mortality 0.37 and fishing mortality 0.37. Radkhah and Eagderi (2015a) gave a *b* value for 30 fish from the Zarrineh River, Lake Urmia basin, 3.6-8.7 cm total length, as 2.59, negative allometric growth. Condition factor was 0.075, indicating poor environmental conditions for this species in contrast to five other cyprinoids studied. Keivany and Zamani-Faradonbeh (2016) gave a *b* value of 2.92 for 13 fish (1.94-3.67 cm total length) from the Talkheh (= Aji) River in the Lake Urmia basin.

Canbolat *et al*. (1999) found life span to be over 9 years in Çıldır Lake, Turkey for *Capoeta capoeta capoeta*. Fish aged 6 years dominated at 31.5% and 61.7% of the sample was female. Life span in Azerbaijan was over 6 years (Abdurakhmanov, 1962) while in Georgia life span exceeded 9 years (Elanidze, 1983).

**Food.** In Maku Dam, this species is a detritivore consuming Chrysophyta from the phytoplankton and the diatom *Cyclotella* from the benthos as well as Chironomidae and Ephemeroptera (Valipour, 2004).

**Reproduction.** Fecundity in the Kura River may reach 93,861 at 36-40 cm (Bănărescu in Bănărescu, 1999). Eggs are shed in running water and on lake shores, and eggs are covered by sand or small stones.

**Parasites and predators.** The crustacean parasite *Tracheliastes polycolpus* is reported from the fins of this species in the Mahabad Dam (Abdi, 1999; www.mondialvet99.com, downloaded 31 May 2000). Jafari *et al*. (2001) isolated the acanthocephalan *Dendronucleata dogieli* from fish in the Zarrineh River, Lake Urmia basin. Masoumian *et al*. (2002) investigated parasites from this fish in the Aras and Mahabad dams and found the protozoan *Myxobolus musayevi*. Mirhasheminasab and Pazooki (2003) listed *Ergasilus peregrinus*, *Tracheliastes polycolpus* and *Lernaea cyprinacea* from this species in Mahabad Dam, the latter being the most dangerous parasite. Araghi Soureh and Jalali Jafari (2005) recorded *Dactylogyrus gracilis*, *D. charmulii*, *D. lenkorani* and *D. kendalanicus* from this species in the Mahabad River of the Lake Urmia basin, the latter species being a new record for Iran. Masoumian *et al*. (2005) recorded the protozoan parasites *Ichthyophthirius multifilis*, *Trichodina perforata*, *Chilodonella*, sp., *Amphileptus branchiarum*, *Tetrahymena pyriformis*, *Apiosoma* sp., and *Vorticella* sp. from this species in water bodies in West Azarbayjan. Masoumian (2007) reported the parasites *Diplozoon megan*, *Trichodina perforata*, *Myxobolus cristatus*, *Tetrahymena pyriformis* and *Amphileptus branchiarum* from fish in the Aras, Ghotor and Zangbar rivers in West Azarbayjan. Pazooki *et al*. (2007) recorded various parasites from localities in West Azarbayjan Province, namely *Diplostomum spathaceum*, *Ligula intestinalis*, *Digramma* sp., *Rhabdochona hellichi*, *Argulus foliaceus*, *Allocreadium isoporum*, *Lamprolegna compacta*, *Myxobolus cristatus* and *M. musajevi*. Barzegar *et al*. (2008) recorded the digenean eye parasite *Diplostomum spathaceum* from this fish in the Maku Dam and other Azarbayjan localities. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Argulus foliaceus* (Maku Dam), *Ergasilus* sp. (Mahabad Dam) and *Tracheliastes*

*polycolpus* (Mahabad Dam and Zarrineh River) on this species. *Ligula intestinalis* was found in fish from Sattarkhan Dam, East Azarbayjan (Hajirostamloo, 2009). Rasouli *et al*. (2011) found the crustacean *Argulus foliaceus* on fish from Marmisho Lake west of Urmia. Rasouli (2013) found the digenean *Diplostomum spathaceum* in fish from Caspian drainages in West Azarbayjan. This parasite causes secondary infections as the metacercariae penetrate the skin and eye, lesions, appetite loss, blurry vision, and reduced feeding. Rasuli and Pourghasem (2015) examined fish from the Zarrineh River in the Lake Urmia basin and found *Trichodina* sp., *Ichthyophthirius multifilis*, *Dactylogyrus lenkorani*, *Paradiplozoon* sp., *Clinostomum complanatum* and *Lernaea* sp. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Dendronucleata dogieli* (Zarrineh River), and *Neoechinorhynchus rutili* and *Pallisentis cholodkowskyi* (both from Mahabad Dam). Rasouli *et al*. (2017) found a contamination of 17.5% for *Diplostomum spathaceum* in Shaharchay Dam Lake, Urmia, this level being higher than acceptable by international standards.

**Economic importance.** *C. capoeta* are commercially important in eastern Georgia and Azerbaijan respectively (Bănărescu in Bănărescu, 1999). It is also used in sport fishing in Iran (Samaee *et al*., 2006).

Shiri *et al*. (2009) and Ramin *et al*. (2012) reported a case of ichthyotoxism after eating fried eggs of this species from Marmisho Lake west of Urmia. Nausea resulted after one minute, and the victim was hospitalised with severe chest pains. No vomiting occurred as this was the only food eaten and symptoms appeared rapidly. Raw consumption should be avoided and even cooked fish or inadequately cleaned fish could be dangerous.

**Experimental studies.** None.

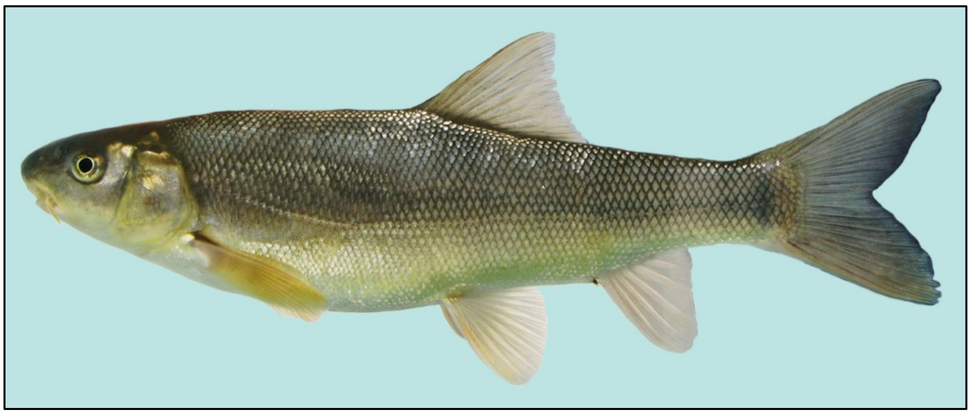
**Conservation.** Population numbers have not been examined and pollution is undoubtedly a factor in smaller streams in the Lake Urmia basin. However, a wide distribution in two basins presumably ensures lessened threat levels.

**Sources.** Zareian *et al*. (2018).

Iranian material:- CMNFI 1970-0557, 3, 18.7-28.2 mm standard length, West Azarbayjan, Shahr Chay (ca. 37º27'N, ca. 44º55'E); CMNFI 1970-0559, 14, 83.9-125.4 mm standard length, West Azarbayjan, Baranduz Chay (ca. 37º25'N, ca. 45º10'E); CMNFI 1970-0560, 1, 60.1, West Azarbayjan, Mamiyand Chay (ca. 36º59'N, ca. 45º39'E); CMNFI 2007-0083, 26, 31.1-55.0 mm standard length, East Azarbayjan, Qaranqu River basin west of Sar Eskand Khan (ca. 37º25'N, ca. 46º55'E); CMNFI 2007-0084, 4, 118.1-173.8 mm standard length, East Azarbayjan, Talkheh River basin west of Sarab (ca. 37º56'N, ca. 47º19'E); CMNFI 2007-0086, 6, 57.1-186.5 mm standard length, Ardabil, Qareh Su basin near Nir (ca. 38º02'N, ca. 48º00'E); CMNFI 2007-0087, 1, 159.6 mm standard length, Ardabil, Qareh Su north of Ardabil (38º22'N, 48º19'E); CMNFI 2007-0088, 5, 39.3-179.0 mm standard length, Ardabil, Qareh Su east of Lari (38º30'N, 48º03'E); CMNFI 2007-0089, 4, 34.9-104.7 mm standard length, East Azarbayjan, Ahar Chay at Ahar (38º28'N, 47º03'E); CMNFI 2007-0091, 10, 40.3-102.0 mm standard length, East Azarbayjan, Zilber Chay basin west of Marand (38º30'N, 45º23'E); CMNFI 2007-0093, 13, 22.6-155.8 mm standard length, West Azarbayjan, Qotur River south of Khvoy (38º30'N, 44º58'E); CMNFI 2007-0094, 6, 167.0-206.3 mm standard length, West Azarbayjan, Nazlu Chay north of Urmia (ca. 37º42'N, ca. 45º04'E); CMNFI 2007-0095, 2, 24.4-31.9 mm standard length, West Azarbayjan, Shahr Chay southwest of Urmia (ca. 37º27'N, ca. 44º56'E); CMNFI 2007-0096, 5, 67.6-85.3 mm standard length, West Azarbayjan, Qasemlu River in Baranduz Chay basin (ca. 37º25'N, ca. 45º10'E); CMNFI 2007-0098, 2, 173.1-196.2 mm standard length, West Azarbayjan, river south of Mahabad (ca. 36º42'N, ca.

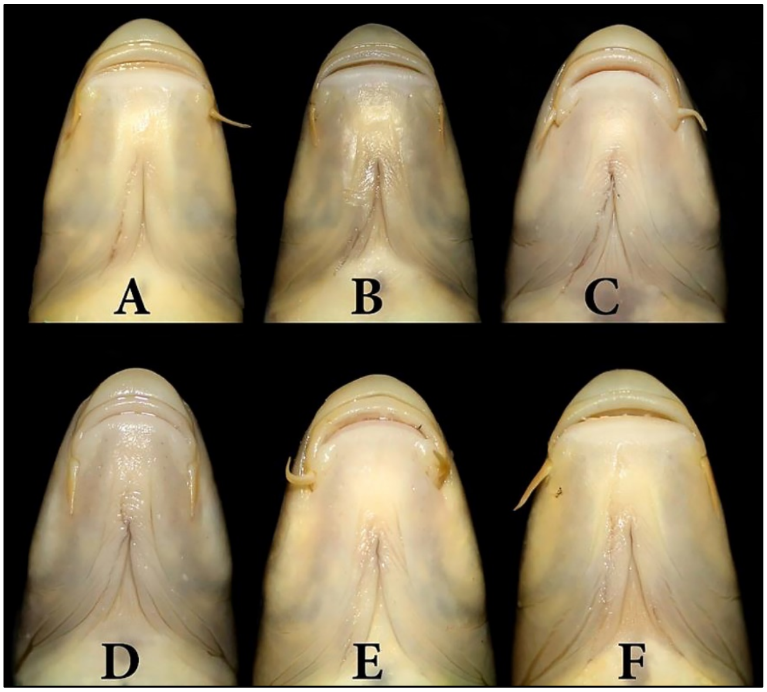
45º41'E); CMNFI 2007-0101, 1, 148.7 mm standard length, West Azarbayjan, Simineh River south of Miandow Ab (ca. 36º54'N, ca. 46º07'E); CMNFI 2007-0102, 4, 142.6-159.0 mm standard length, West Azarbayjan, Zarrineh River near Miandow Ab (ca. 37º00'N, ca. 46º07'E); CMNFI 2007-0103, 9, 30.1-59.4 mm standard length, Kordestan, Zarrineh River basin north of Saqqez (ca. 36º18'N, ca. 46º16'E); CMNFI 2007-0104, 4, 132.9-166.4 mm standard length, Kordestan, Zarrineh River basin south of Saqqez (ca. 36º12'N, ca. 46º18'E); CMNFI 2007-0105, 7, 35.6-133.2 mm standard length, Kordestan, Zarrineh River basin south of Saqqez (ca. 36º06'N, ca. 46º20'E); CMNFI 2008-0158, 1, 66.7 mm standard length, Lake Urmia basin (no other locality data).

## *Capoeta coadi*
Alwan, Zareian and Esmaeili, 2016



*Capoeta coadi*, Kohgiluyeh and Bowyer Ahmad, Beshar River, after Alwan *et al*. (2016).

*Capoeta coadi*, Kohgiluyeh and Bowyer Ahmad, Beshar River (above)
and Esfahan, Zayandeh River (below), after Jouladeh-Roudbar *et al*. (2020).




*Capoeta coadi*, ventral heads,
A, 159 mm standard length, IMNRF-UT-1108 30,
B, 163 mm standard length, IMNRF-UT-1108 32,
C, 156 mm standard length, IMNRF-UT-1108 34,
D, 138 mm standard length, IMNRF-UT-1108 35,
E, 153 mm standard length, IMNRF-UT-1108 37 (*sic*),
E, 143 mm standard length, IMNRF-UT-1108 40 (*sic*),
F, 132 mm standard length, IMNRF-UT-1108 43,
after Jouladeh-Roudbar *et al*. (2017, Soheil Eagderi.

*Capoeta birunii* (= *C. coadi*) Esfahan, Daran River, Hamid Reza Esmaeili.

**Common names.** Siyah mahi Karun, siyah mahi Coad.

[Coad’s scraper, Coad barb, Karun scraper; and *C. birunii* was named Esfahan scraper].

**Systematics.** The holotype is under ZM-CBSU (Zoological Museum of Shiraz University, Collection of Biology Department, Shiraz) Z190, 157 mm standard length, Iran, Kohgiluyeh and Bowyer Ahmad, Beshar (Bashar) River at Tale Gah village, Karun River drainage, 30º47'27"N, 51º25'13"E. Paratypes are ZM-CBSU Z191, 6, 91-157 mm standard length, same data as holotype; ZM-CBSU J520, 1, 107 mm standard length; ZM-CBSU Z275, 12, 105-152 mm standard length; same data as holotype; ZM-CBSU J526, 1, 98 mm standard length; ZM-CBSU J533, 1, 114 mm standard length; ZM-CBSU J535, 1, 97 mm standard length; ZM-CBSU J540, 1, 67 mm standard length; all from Beshar River at Tang-e Sorkh,

Karun River drainage, 30°26'14"N, 51°45'48"E; ZM-CBSU J444, 2, 73-90 mm standard length; ZM-CBSU J447, 2, 76-111 mm standard length; ZM-CBSU J450, 1, 86 mm standard length; ZM-CBSU J452, 1, 107 mm standard length; ZM-CBSU J459, 2, 104-120 mm standard length; ZM-CBSU J464, 1, 110 mm standard length; all from Beshar River at Mokhtar village, Karun River drainage, 30°40'31"N, 51°31'26"E. *C. coadi* was named after Brian W. Coad, a well-known ichthyologist for his valuable contribution to the knowledge of freshwater fishes of Iran.

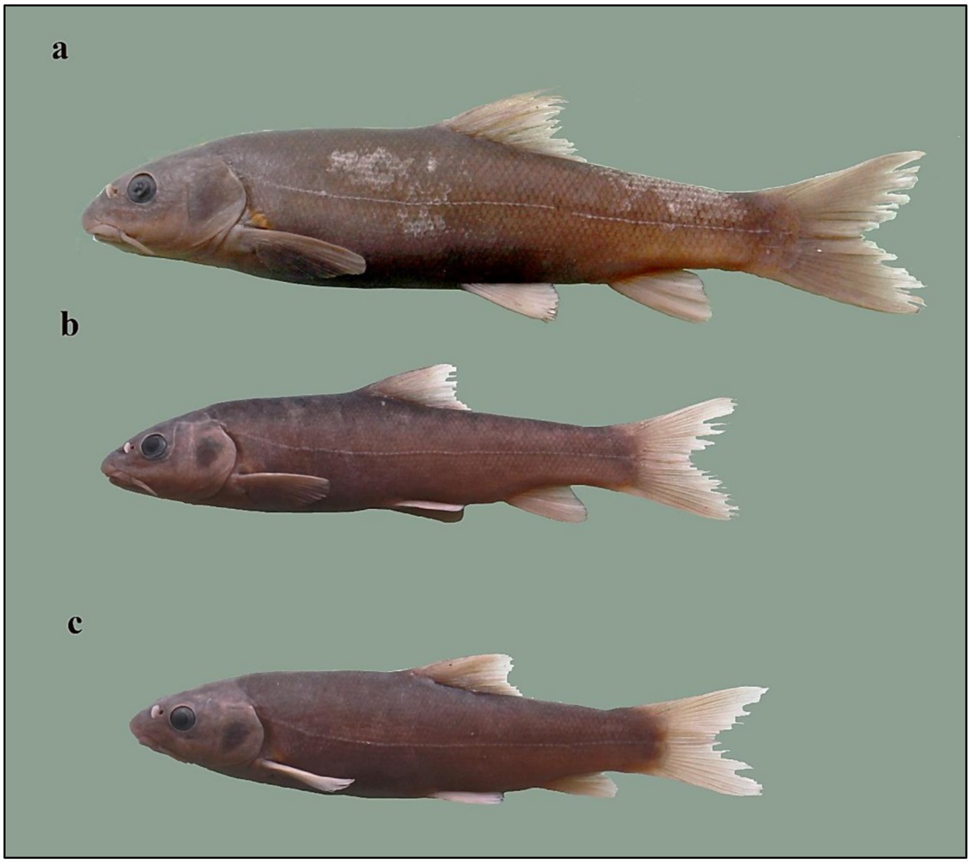
Jouladeh-Roudbar *et al*. (2020) noted that Ghanavi *et al*. (2016) identified the small-scaled *Capoeta* in the Esfahan basin as *C. coadi* but Zareian and Esmaeili (2017) described these fish as a new species, *C. birunii*. Jouladeh-Roudbar *et al*. (2020) compared the sequences of *C. birunii* and *C. coadi* deposited in GenBank and found a genetic distance less than 0.5%, concluding that the genetic distances in Zareian and Esmaeili (2017) were in error. Additionally, morphological characters overlap and thus *C. birunii* was synonymised with *C. coadi*.

*Capoeta coadi*, holotype, ZM-CBSU Z190, after Alwan *et al*. (2016).


*Capoeta coadi*, paratypes, 157.0 mm standard length, ZM-CBSU Z191, 148.0 mm standard length, ZM-CBSU Z192 (*sic*, latter not in text as paratype), after Alwan *et al*. (2016).

The holotype of *C. birunii* is under ZM-CBSU Z650 (Zoological Museum of Shiraz University, Collection of Biology Department, Shiraz), 141 mm standard length, Esfahan, Daran River near Daran, Zayandehrud basin, 32˚49′25.8″N 50˚25′47.4″E with paratypes under

ZM-CBSU Z651-660, 10, 90-165 mm standard length, same data as holotype. The species was named after Abū Rayḥān Bīrūnī (4 September 973-9 December 1048), known as Al Biruni in English. He was an Iranian scholar and polymath.



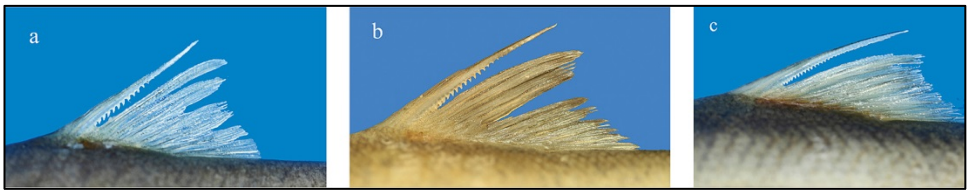

*Capoeta birunii* (= *C. coadi*), a) holotype, ZM-CBSU Z650,
b) paratype, 105.0 mm standard length, ZM-CBSU Z651,
c) paratype, 104.0 mm standard length, ZM-CBSU Z652,
Hamid Reza Esmaeili.

Earlier studies on fish from the upper Karun River basin identified them as *C. damascina*, a species now restricted to the Levant (see discussion under the genus above). The species is presumably *C. coadi* based on distribution and these studies have been transferred here. Material from the Esfahan basin with high lateral line scale counts and low gill raker counts are here identified as *C. coadi* but these populations need further molecular work to elucidate the taxonomy.

**Key characters.** This species is distinguished from other small-scaled *Capoeta* species (61 or more lateral line scales) by having 12-17 scales between the dorsal fin origin and the lateral line, the body and head without irregular brown to black speckles, total gill rakers 12-18, dorsal fin branched rays modally 8, and a distribution in the Karun River basin of the Tigris River basin and the Esfahan basin.

**Morphology.** The body is elongate and cylindrical. The predorsal body profile is smoothly convex to almost straight running onto the head. The dorsal head profile is straight and may have a groove in front of the nostrils. The greatest body depth is at the level of the dorsal fin origin or slightly in front. The snout is rounded or pointed and overlaps the upper lip. A nuchal hump may be present. The mouth is inferior, the lips moderate to thick and slightly

fleshy, thickest at the mouth corners. The lower lip is covered with a sharp-edged horny sheath, with its anterior margin straight in adult specimens and rounded to almost crescent-shaped in juveniles, with a considerable degree of individual variation. Some fish lack an evident horny edge. The barbel is thick and reaches back to the mid-eye level or slightly past it. One fish out of 51 had two pairs of barbels. The rear of the eye is at the beginning of the anterior half of the head. The dorsal fin origin is anterior to the level of the pelvic fin origin, its outer margin is usually straight to concave. The last unbranched dorsal fin ray is weakly to moderately ossified, flexible and soft at the tip, and serrated on one-third to two-thirds of its length. The depressed dorsal fin does not extend back to the level of the anal fin origin.




*Capoeta coadi*, dorsal fin spine variation,
a = 73.0 mm standard length, b = 104.0 mm standard length, c = 148.0 mm standard length,
after Alwan *et al*. (2016).

Dorsal fin spines,
*Capoeta coadi*, 163 mm standard length, IMNRF-UT-1108 32,
*Capoeta ferdowsii*, 135 mm standard length, IMNRF-UT-1111 65,
*Capoeta shajariani*,167 mm standard length, IMNRF-UT-1107 23,
after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

The caudal fin is moderately forked and the tips are pointed to rounded, the ventral tip especially being rounded. The anal fin margin is straight or slightly convex. The pelvic fin is short, not extending back to the anal fin base and its margin is straight or slightly convex and blunt. The pectoral fin does not extend to the pelvic fin base and its margin is usually slightly convex.

Dorsal fin with 3-5 unbranched and 7-9 branched rays, usually 8, anal fin with 3 unbranched rays and 5 branched rays, pectoral fin branched rays 16-22, and pelvic fin branched rays 7-11. Lateral line scales 68-84, scales between dorsal fin origin and lateral line 12-17, scales between anal fin origin and lateral line 7-11, and scales around caudal peduncle 20-33. Scales on the ventral midline and pectoral region are small and deeply embedded. A long pelvic axillary process is present comprised of up to three scales. Scales are squarish, rounded on the posterior margin, slightly rounded on the dorsal and ventral margins, and weakly to strongly protruding centrally with an indentation above and below on the anterior

margin. Anterior corners are rounded. There are few circuli, many radii on all fields with lateral ones curved, and a subcentral anterior focus. Total gill rakers number 12-19, with 10-13 on the lower arch, are slightly hooked, and reach past the adjacent raker when depressed. Pharyngeal teeth are 2,3,5 or 4-5 or 4,3,2, main row teeth being spatulate or spoon-shaped with flat, narrow and curved crowns. The fifth main row tooth may be very small. The gut is elongate with several long coils. Total vertebrae number 44-47. Dorafshan and Roozdar (2016) reported a chromosome count of 147-152, mode 150, characterised as hexaploid, in fish from the Monj River in the upper Karun River basin identified as *C. damascina* but presumably *C. coadi*.

Jawad and Alwan (2020) gave comparative details of the vertebral column and dorsal, anal and caudal fins in a study of the osteology of the *Capoeta damascina* species complex.

Meristic values are:- pectoral fin branched rays 16(6), 17(10), 18(8), 19(11), 20(7), 21(1) or 22(2), pelvic fin branched rays 7(1), 8(14), 9(16), 10(12) or 11(8), lateral line scales 70(2), 71(1), 72(2), 73(6), 74(1), 75(4), 76(4), 77(1), 78(5), 79(3), 80(5), 81(6), 82(5), 83(1) or 84(1), and total gill rakers 14(1), 15(7), 17(6) or 18(5), all after Alwan *et al*. (2016); and based on my material dorsal fin branched rays 7(1), 8(34) or 9(1), anal fin branched rays 5(36), pectoral fin branched rays 18(8), 19(4), 20(9), 21(10) or 22(1), pelvic fin branched rays 8(2), 9(29) or 10(5), lateral line scales 69(2), 70(2), 71(4), 72(1), 73(4), 74(2), 75(3), 76(3), 77(1), 78(1), 79(1), 80(-), 81(-), 82(-), 83(-) or 84(2), scales above the lateral line 14-17, caudal peduncle scales 26-33, total gill rakers 12(3), 13(7), 14(9), 15(4), 16(1) or 17(2), and total vertebrae 44(7), 45(20) or 46(5).

**Sexual dimorphism.** Males have more developed breeding tubercles than females. In CMNFI 1979-0242 (107.0 mm standard length, 8 June 1977) tubercles are present on the sides of the snout between the nostril and the mouth, and are smaller on the side of the head below and behind the eye and over the eye. Those on top of the head are the smallest. Tubercles may cover the entire body surface. They are found on and above the lateral line with one or two tubercles per scale, rarely three, but not on each scale, and below the lateral line especially in the area above the anal fin. Some tubercles are found mid-scale but most are found posteriorly on the scale. The largest tubercles are on anal fin branched rays 1-4, being few and distal. The tip of the anal fin reaches to or beyond the vertical of the caudal fin base in females and to about two-thirds of the caudal peduncle in males.

**Colour.** The back and flanks are bright golden-green, golden-brown or silvery, darker dorsally and lighter below the lateral line. The belly is white. The dorsal head is bright golden-green or light pink-brown. The operculum is white, silvery or golden. The outer margin of the eyes is golden. The dorsal, anal and caudal fins are beige to light brown with a light pink to red tinge. The pectoral and pelvic fins are beige to light brown or golden-yellow with a brown tinge on the first few rays. The base of the caudal fin is golden. There are a few large black blotches present on the body of some specimens whereas small diffuse black spots are present only on the body of some juveniles above the lateral line. In preserved fish, the back, head and flanks are grey or brownish-grey dorsally and beige or yellow ventrally. The dorsal and caudal fins are dusky grey, although the caudal fin can be quite dark. The pectoral, pelvic and anal fins are white or beige with or without a grey tinge. Blotches and spots are well discernible.

**Size.** Attains 33.3 cm total length (Alavi-Yeganeh *et al*., 2018) or 54.2 cm total length as *C. damascina* in the Zayandeh River and presumably this species (Asadollah *et al*., 2017).

**Distribution.** This species is found in the Esfahan and Tigris River basins in Iran, mostly in the upper Karun River basin of the latter and possibly also the Karkheh River (Alwan

*et al*., 2016). In the Esfahan basin it is recorded from the Daran, Izadkhvast and Zayandeh rivers; and in the Tigris River basin from the Dasht-e Rum, Dez, Gorgu, Hadi, Karun, Kashkan, Khersan, Kuhrang, Sandgan (= Sangan), Sarkhan, Semeh, Tang-e Sorkh and Tang-e Tizab rivers (Alwan *et al*., 2016, 2016; Ghanavi *et al*., 2016; Jouladeh Roudbar *et al*., 2016, 2017; Zareian and Esmaeili, 2017; Alavi-Yeganeh *et al*., 2018; Fatemi *et al*., 2019; Jouladeh-Roudbar *et al*., 2020). Material from the Morghab River is probably this species (Alwan *et al*., 2016). Records of *C*. *damascina* from the Armand, Bazoft, Beheshtabad, Beshar and Monj rivers, Salm Lake and Gandoman Wetland in the upper Karun River basin may be this species (Molnár and Jalali, 1992; Raissy *et al*., 2010; Raissy and Ansari, 2012; Siami *et al*., 2014, 2014b, 2014c, 2017; Tabiee *et al*., 2014; Dorafshan and Roozdar, 2016; Raissy *et al*., 2020; and **Sources** below). Records of *C*. *damascina* from the Kaaj River in the upper Karun River basin may be this species as *C*. *aculeata* (= *C*. *macrolepis*) was distinguished (Raissy *et al*., 2013).

**Zoogeography.** This species is most closely related to *C*. *buhsei* of the Namak Lake basin based on DNA evidence. It is a member of the *C*. *damascina* species group (see above under the genus account) which diverged from the *C*. *capoeta* group about 9.1 MYA. The Iranian members of the *C*. *damascina* group form a sister clade to other group members (*C*. *damascina*, formerly used widely for fish from Iran, is restricted to the Damascus area in Syria (Alwan *et al*., 2016)).

**Habitat.** This species is found in rivers and streams with slow to medium-fast current, usually over a gravel substrate but also mud, sand and pebbles, in clear or cloudy water, with encrusting vegetation, and with riparian vegetation such as grasses or forest. Capture sites were 4-80 m wide with pH 6.2 and temperature 17ºC. The Beshar River site was about 25 m wide with coarse gravel and boulders, fast flowing semi-transparent water, dissolved oxygen 9.89 mg/l, total dissolved solids 190.2 mg/l, salinity 0.19‰, conductivity 395 µS/cm, pH 8.5, and water temperature 23.4ºC. Details of the Zayandeh River are given above under **Environment** and see photographs below.

*Capoeta coadi* type locality, Kohgiluyeh and Bowyer Ahmad, Beshar River at Taleh Gah village, Karun River basin, after Alwan *et al*. (2016).

Habitat of *Capoeta birunii* (= *coadi*), Esfahan, Zayandeh River near Daran, Hamid Reza Esmaeili.

**Age and growth.** Asadollah *et al*. (2011) found fish identified as *C. damascina* and presumably *C. coadi* up to $10^+$ years in the Zayandeh River, the oldest fish being female, and the most frequent age classes being $3^+$ for males and $4^+$ for females. Asadollah *et al*. (2017) examined 689 fish, 10.0-48.8 cm fork length, from the Zayandeh River and found age groups $1^+$ to $9^+$ for males and $1^+$ to $10^+$ for females, a male:female sex ratio 1:1.6 not significantly

different from 1:1, maximum length and weight were 39.0 cm and 1,115 g for males and 54.2 cm and 2,340 g for females, females were larger than males at all age classes, the most frequent age classes were $3^+$ in males and $4^+$ in females, the highest condition factor was in June, the von Bertalanffy growth parameters were $L_\infty$ = 56.2 cm, k = 0.098, and $t_0$ = -0.628 for males and $L_\infty$ = 117.12 cm, k = 0.05, and $t_0$ = -0.432 for females, growth performance index was estimated at 5.73 for males and 6.53 for females indicating faster growth in the latter, and the length-weight relationship was $W = 0.0169L^{2.9469}$ for males and $W = 0.0155L^{2.9867}$ for females indicating isometric growth.

Siami *et al*. (2014a) found fish from the Beheshtabad River in Chahar Mahall and Bakhtiari Province identified as *C. damascina* to reach $7^+$ years with females growing faster than males in age groups 4-7 years. Siami *et al*. (2014b) found opercula were better structures for age determination than scales. Keivany *et al*. (2015) gave a *b* value of 2.79 (negative allometric growth) for 127 fish, 16.0-493.0 cm total length, from the Beheshtabad River. Siami *et al*. (2017) examined 426 fish, 8.94-42.45 cm fork length, from the Beheshtabad River and found a maximum age of $7^+$ for males and $8^+$ for females. Keivany and Siami (2020) examined 426 specimens from the Beheshtabad River collected from May 2013 to May 2014. The male:female sex ratio was 1:0.7, the maximum ages of the population were $8^+$ years for females and $7^+$ for males and the most frequent age groups were $3^+$ and $4^+$ in males and females, respectively. Size varied from 8.94 to 42.95 cm (or 42.45 cm) in fork length and weight between 10.3 and 1,255.5 g. The length-weight relationship implied that the growth was negatively allometric for both sexes. The von Bertalanffy growth model was estimated as $L_t = 35.97[1-e^{-0.205(t+0.586)}]$ and $L_t = 49.31[1-e^{-0.162(t-0.208)}]$ for males and females, respectively. The growth performance index was estimated at 5.58 and 5.97 for males and females, respectively, indicating a faster growth rate for females.

Esmaeili *et al*. (2014) gave a *b* value for 66 fish identified as *C. damascina* from the Esfahan basin, 3.36-17.5 cm total length, as 3.0. Alavi-Yeganeh *et al*. (2018) found a total length *b* value of 1.199 (and 0.935 for standard length) for 91 fish, 5.2-33.3 cm total length, from the Kuhrang River identified as *C. coadi*. Zareian *et al*. (2018a) gave a *b* value of 2.801 for 32 fish, 5.7-18.0 cm total length identified as *C. coadi*. Zareian *et al*. (2018a, 2018b) gave a *b* value of 2.469 for 28 fish identified as *C. birunii*, 4.4-19.6 cm total length. Zare-Shahraki *et al*. (2020) measured 1.084 fish, 2.6-26.8 cm total length, from the Karun River system and recorded a *b* value of 2.92.

**Food.** Siami *et al*. (2014c) found fish from the Beheshtabad River identified as *C. damascina* to have a condition factor of 4.67 and a relative gut length of 1.18, indicating an herbivorous fish.

**Reproduction.** Asadollah *et al*. (2011) examined reproduction in fish from the Zayandeh River identified as *C. damascina*. The male:female sex ratio was 1:1.57. Males matured at $2^+$ years and females between ages 4 to 6 years with 100% maturity at age $7^+$ years. Gonadosomatic indices indicated reproduction in May and June at 12.6-16.6°C and it was group-synchronous. Absolute fecundity reached 72,645 eggs (mean 24,811 eggs), with $4^+$ females averaging 9,446 eggs and $8^+$ females 54,503 eggs. The mean relative fecundity was 28.7 eggs/g. Mean egg diameter was highest in May at 1.81 mm. Siami *et al*. (2017) examined 426 fish from the Beheshtabad River identified as *C. damascina* and found the smallest mature male was 11.2 cm and the smallest female 18.5 cm fork length, the male:female sex ratio was 1:0.7, age at first maturity was ≤2 years for males and $3^+$ for females, the highest gonadosomatic indices were in March for males and May for females, the average

gonadosomatic indices were 3.92 for males and 4.96 for females (significantly different), spawning occurred from March to June, egg diameters were 0.57-2.48 mm, mean 1.3 mm, with a mean maximum at 2.05 mm in May (the abstract gave minimum egg diameter as 0.57 mm, the text 0.52 mm), absolute fecundity was 2,260-51,770 eggs, mean 15,360 eggs, relative fecundity was 11-65 eggs/g, mean 33 eggs/g, and the average hepatosomatic index was 2.25 with the highest value, 3.05, in March.

**Parasites and predators.** Various parasites have been reported from fish in the upper Tigris River basin and the Zayandeh River, with various identities before *C. coadi* was described. They may be *C. coadi*, or *C. macrolepis* (Tigris), or *C. gracilis* (Zayandeh). Williams *et al*. (1980) reported the helminths *Khawia armeniaca* (a cestode) and *Acanthocephalorhynchoides cholodkowskyi* (an acanthocephalan) from *C. buhsei* in the Zayandeh River at Esfahan and these fish may have been *C. coadi*. Molnár and Jalali (1992) recorded the monogeneans *D. chramulii* and *D. lenkorani* for fish identified as *C. capoeta* in the Beshar River of the Tigris River. Barzegar *et al*. (2004) and Barzegar and Jalali (2009) examined fish identified as C. *damascina* for parasites from the Beheshtabad River in Chahar Mahall and Bakhtiari Province and found *Dactylogyrus lenkorani*, *Gyrodactylus pulcher*, *Dactylogyrus* sp., *Allocreadium isoporum*, *Myxobolus molnari* and *Lernaea cyprinacea*. Mehdipoor *et al*. (2004) recorded the monogeneans *Dactylogyrus lenkorani* and *D. pulcher* in Zayandeh River fish identified as *C. damascina*. Masoumian *et al*. (2007) recorded the myxosporean parasites *Myxobolus samgoricus* and *M. varicorhini* from *C. damascina* in the Zayandeh River. Barzegar *et al*. (2008) recorded the digenean eye parasite *Diplostomum spathaceum* from fish identified as *C. damascina* in the Zayandeh River. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Pallisentis cholodkowskyi* from fish in the Zayandeh River and Dam identified as *C. damascina*. Raissy *et al*. (2009) found that fish identified as *C. damascina* had the highest infection rate with *Lernaea cyprinacea* among several fish species in the Choghakhor (= Chagha Khur) Lagoon in the upper Karun River basin of Chahar Mahall and Bakhtiari Province. Raissy *et al*. (2010) found ichthyophthiriasis (infection with *Ichthyophthirius multifilis* - ich or white spot disease), which can cause epizootics in wild and cultured fishes, in fish identified as *C. capoeta* and *C. damascina* from the Armand River in Chahar Mahall and Bakhtiari Province. Raissy and Ansari (2012) also examined these fish from the Armand River and found a wide range of parasites including a ciliophoran (*Ichthyophthirius multifilis*), a myxozoan (*Myxobolus musayevi*), monogeneans (*Dactylogyrus chramuli*, *D. gracilis*, *D. lenkorani*, *D. pulcher*, *D. skrjabiensis*, *Gyrodactylus* sp., *Paradiplozoon* sp.), digeneans (*Allocreadium isoporum*, *A. pseudaspii*), a crustacean (*Lamproglena compacta*) and a nematode (*Rhabdochona denudata*), and these may be referable to *C. coadi* as *C. aculeata* (= *C. macrolepis* in this locality) was distinguished in both these papers. Similarly, Raissy *et al*. (2013) recorded from fish in the Kaaj River in the upper Karun River basin *Ichthyophthirius multifilis* (Ciliophora), *Dactylogyrus lenkorani* and *Gyrodactylus* sp. (Monogenea), *Allocreadium isoporum* (Digenea), and *Rhabdochona* sp. (Nematoda). Pirali-khierabadi *et al*. (2014) recorded the protozoans *Ichthyophthirius multifilis* and *Trichodina* sp. and Pirali-Khierabadi *et al*. (2015) identified the metazoans *Dactylogyrus lenkorani*, *Gyrodactylus elegans*, *Myxobolus varicorhini* and *Rhabdochona denudata* in fish identified as *C. damascina* from the Bazoft River, Chahar Mahall and Bakhtiari Province. Raissy *et al*. (2020) compared the effects of geranium, lavender and garlic extracts on *Ichthyophthirius multifilis* or white spot disease in naturally infected fish identified as *Capoeta damascina* and from Salm Lake, Kiar, Chahar Mahall and Bakhtiari, finding garlic to be

especially useful.

**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** Jouladeh-Roudbar *et al*. (2020) listed this species as of Least Concern based on its many populations across its distribution with no known major threats.

**Sources.** Alwan *et al*. (2016).

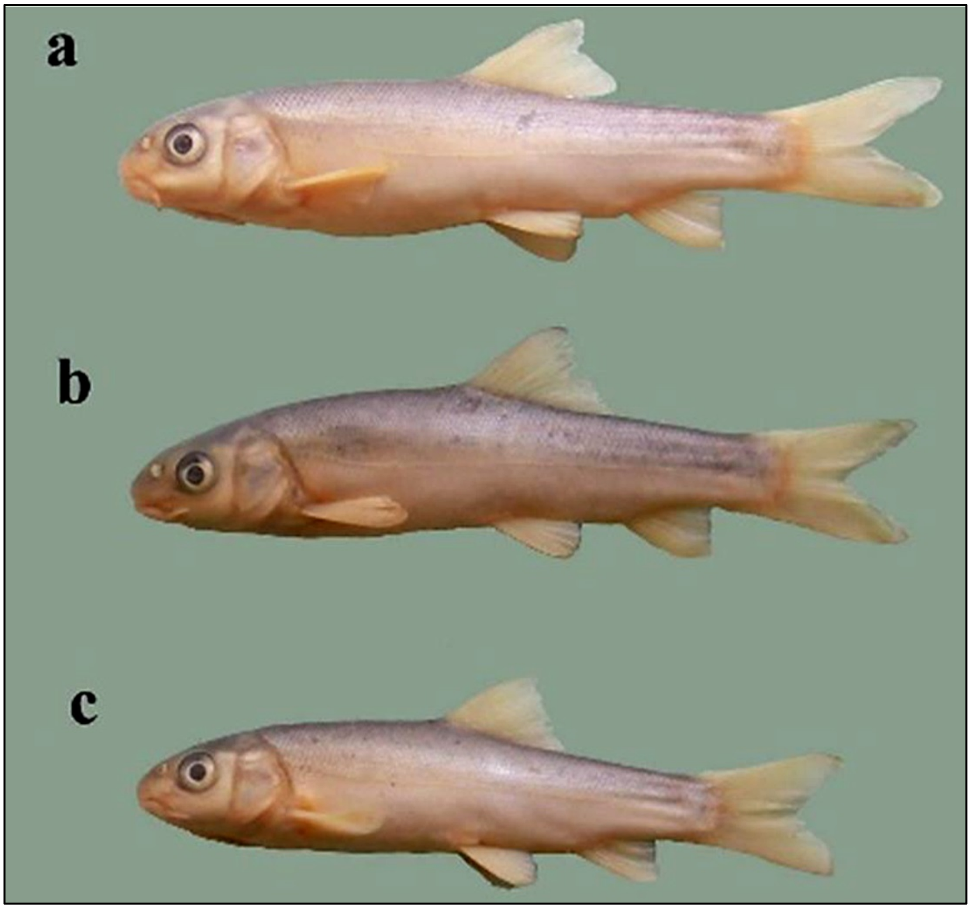
Iranian material: CMNFI 1979-0090, 3, 49.9-77.2 mm standard length, Esfahan, Gav Khuni (ca. 32º21'N, ca. 52º49'E); CMNFI 1979-0242, 27, 25.6-107.0 mm standard length, Fars, Izadkhvast River (31º31'N, 52º07'E); CMNFI 1979-0249A, 33, 66.4-114.2 mm standard length, Esfahan, stream at Dizaj (31º55'N, 51º30'E); CMNFI 2008-0182, 1, 109.5 mm standard length, Chahar Mahall and Bakhtiari, Ab-e Bazoft Sofla (31º38'06"N, 50º28'30"E); CMNFI 2008-0184, 1, 85.1 mm standard length, Chahar Mahall and Bakhtiari, Armand River (31º37'N, 50º47'E).

### *Capoeta ferdowsii*

Jouladeh-Roudbar, Eagderi, Murillo-Ramos, Ghanavi and Doadrio, 2017

*Capoeta ferdowsii*, 138 mm standard length, IMNRF-UT-1111 67, Fars, Tang-e Shiv River at Bekr Sofla Village, after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

*Capoeta ferdowsii*, ZM-CBSU Z700-708, Fars, Doshmanzeyari River near Nurabad, Hamid Reza Esmaeili.




*Capoeta ferdowsii*, Fars, Doshmanzeyari River near Nurabad,
a) 58.0 mm standard length, ZM-CBSU Z700, b) 57.0 mm standard length, ZM-CBSU Z701,
c) 50.0 mm standard length, ZM-CBSU Z702, Hamid Reza Esmaeili.

**Common names.** Siyah mahi Ferdowsi.

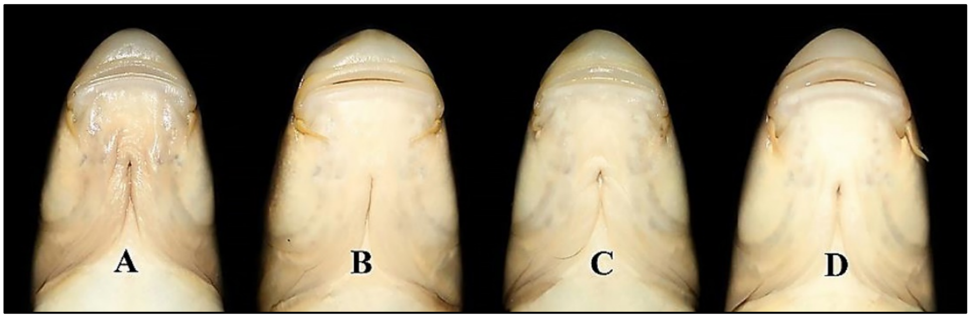
[Ferdowsi scraper, Zohreh scraper].

**Systematics.** The holotype is under IMNRF-UT-1111 61 (Ichthyological Museum of Natural Resources Faculty, University of Tehran, Karaj), 121.6 mm standard length, Fars, Tang-e Shiv River at Bekr Sofla village, Zohreh River drainage and paratypes are IMNRF-UT-1111, 8, 63.8-138.4 mm standard length, same data as the holotype. The species is named to honor of Abu Al-Qasim Ferdowsi Tusi, a Persian poet and the author of the Shahnameh, a book which is the world’s longest epic poem and the national epic of Greater Iran.

Jouladeh-Roudbar *et al*. (2020) noted that Esmaeili *et al*. (2018) mistakenly gave the type locality of *C. coadi* for this species.

*Capoeta ferdowsii*, holotype, IMNRF-UT-1111 61,
after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.


*Capoeta ferdowsii*, paratypes, A, 130 mm standard length, IMNRF-UT-1111 62,
B, 112 mm standard length, IMNRF-UT-1111 63, C, 112 mm standard length,
IMNRF-UT-1111 64, after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.




*Capoeta ferdowsii*, A, holotype, 122 mm standard length, IMNRF-UT-1111 61,
paratypes, B, C, D (as A, B, C above), after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

**Key characters.** This species is distinguished from other small-scaled *Capoeta* species (61 or more lateral line scales) by having 13-17 scales between the dorsal fin origin and the lateral line, the body and head without irregular brown to black speckles, total gill rakers 13-18, dorsal fin branched rays modally 8, and a distribution in the Zohreh River basin of the Persis basin.

**Morphology.** The body is elongate and cylindrical, the greatest body depth is somewhat after the posterior end of the pectoral fin or at the dorsal fin origin, the predorsal body profile is convex with a narrow keel in front of the dorsal fin origin, and the ventral profile is straight or slightly convex. The caudal peduncle is compressed and moderately deep. The snout is rounded, blunt, and triangular in ventral view, the width markedly larger than the inter-nasal distance. The rear of the eye is at the beginning of the anterior half of the head. The mouth is wide, straight to arcuate in shape and sexually dimorphic, its width about equal to the interorbital distance. The rostral cap is well-developed and covers the upper lip centrally. The upper and lower lips are adnate to the jaws, and the lower jaw is covered with a keratinized edge. The lower lip has small lateral lobes. The dorsal head profile is slightly convex, with no marked hump between the head and the body. There is a groove across the head in front of the nostrils. The thick maxillary barbel reaches a vertical from the anterior margin of the pupil. The dorsal fin origin is slightly anterior to the level of the pelvic fin origin. The dorsal fin margin is concave. The pelvic fin insertion is positioned posterior to the first branched dorsal fin ray. The last unbranched dorsal fin ray is weakly to moderately ossified, serrated and flexible distally, with 15-23 long denticles along 40-60% of its posterior margin, narrowly spaced and moderately strong. The dorsal fin when depressed almost reaches the level of the anus. The caudal fin is moderately forked with the lower lobe slightly more rounded than the upper lobe. The anal fin margin is straight to rounded or slightly concave. The depressed anal fin is remote from or almost reaches the base of the caudal fin. The pelvic fin margin is straight to rounded and the pectoral fin margin is rounded. The pelvic fin does not reach back to the anal fin origin and the pectoral fin does not reach back to the pelvic fin origin.

Dorsal fin with 4-5 unbranched and 7-9 branched rays, anal fin with 3 unbranched and 5 branched rays, pectoral fin branched rays 15-18, and pelvic fin branched rays 7-8. The complete lateral line has 68-83 scales, there are 13-17 scales between the dorsal fin origin and the lateral line, 8-11, modally 9, between the anal fin origin and the lateral line, and 23-30 circumpeduncular scales. The ventral midline and pectoral area have deeply embedded scales of reduced size. There is a well-developed pelvic axillary scale, triangular in shape and pointed. Scale shape is squarish to horizontally rectangular. The posterior margin is rounded and the dorsal and ventral margins are gently rounded. The anterior scale corners are sharp but rounded with the ventral corner more rounded. The anterior margin has a central protrusion with an indentation above and below. The focus is subcentral anterior. There are numerous fine circuli and numerous radii are present on all fields, those on the lateral fields being curved. Total gill rakers number 13-18, 10-13 on the lower limb, the longest raker reaching the raker below or just past it when depressed. A single specimen listed below falls within these original description meristic values as well as pelvic fin origin to anal fin origin distance as percent of standard length (23.4-25.8%) and postorbital length as percent of head length (42.8-48.5%). Pharyngeal teeth number 2,3,5 on each side with the fifth tooth reduced to a nub. Major row teeth are scalloped with curved, flat crowns. Total vertebrae 44.

**Sexual dimorphism.** Tubercles are absent on the head in the original description but all *Capoeta* species are tuberculate in varying degrees.

**Colour.** The body is entirely silverish to brown or olive-green, the upper flank brownish, and the belly and lower flank cream up to the lateral line. Flanks are silvery or white. Some specimens have small black spots or blotches scattered on flanks and some have a diffuse lateral band along the sides and small diffuse black spots above the lateral line. The dorsal, anal, pelvic and caudal fins are cream in colour. The pectoral fins are reddish-brown to yellowish. The bases of the dorsal, pelvic and pectoral fins are orange. The iris is silverish or golden. Preserved fish have the head and back dark-brown or brownish to olive, flanks cream or white, and the body is lighter below the lateral line. The caudal and dorsal fins have melanophores on the rays without any distinctive pattern. The peritoneum is black.

**Size.** Reaches 15.1 cm standard length.

**Distribution.** This species is found in the Persis basin of Iran in the Doshmanzeyari, Fahlian, Shesh Pir, Tang-e Shiv and Zohreh rivers (Jouladeh-Roudbar *et al*., 2017; Shirmohamadi *et al*., 2017; Zareian and Esmaeili, 2017; Fatemi *et al*., 2019).

**Zoogeography.** See under the genus.

**Habitat.** This species is found in rivers and streams with medium to fast flowing clear, cloudy or muddy water, medium to fast current, mud, sand, pebble, stone and boulder bottoms, cold water (12ºC, 18 May 1978, CMNFI 1979-0420), encrusting vegetation, and a barren, grassy or bushy shore.

Type locality of *Capoeta ferdowsii*, Fars, Tang-e Shiv River at Bekr Sofla Village, after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

Habitat of *Capoeta ferdowsii*, Fars, Doshmanzeyari River near Nurabad,
Hamid Reza Esmaeili.

**Age and growth.** Zareian *et al*. (2018a) gave a *b* value of 2.865 for 23 fish, 3.8-7.0 cm total length.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

**Economic importance.** None.

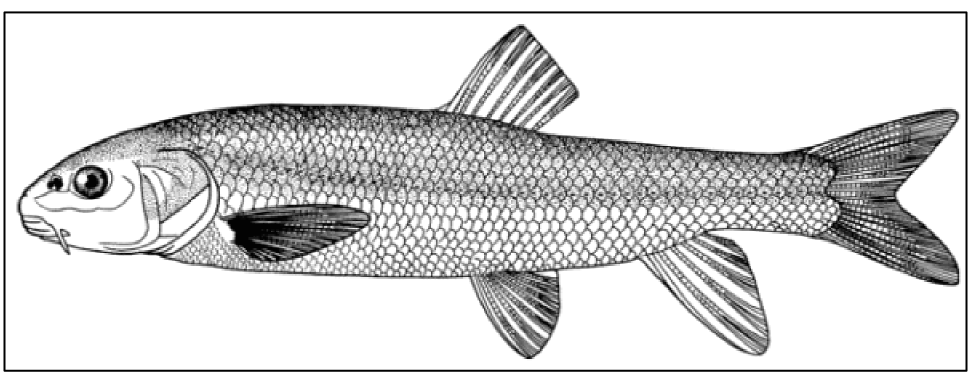
**Experimental studies.** None.

**Conservation.** Jouladeh-Roudbar *et al*. (2020) listed this species as Near Threatened since it has a limited distribution in rivers faced with severe droughts and loss of habitats and there are unknown threats from water extraction, agriculture and pollution.

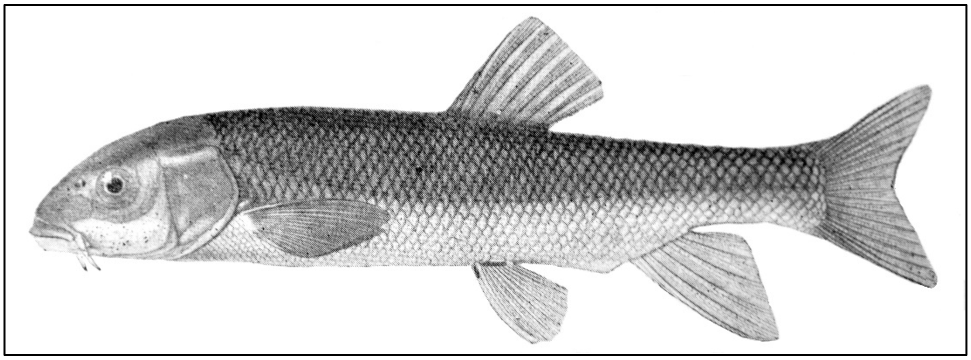
**Sources.** Jouladeh-Roudbar *et al*. (2017).

Iranian material:- CMNFI 1979-0420, 1, 150.6 mm standard length, Fars, Shesh Pir River, 11 km south of Ardakan (30º11'N, 52º03'E).

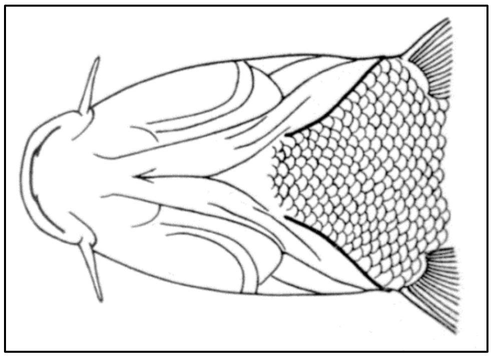
## *Capoeta fusca*
Nikol'skii, 1897



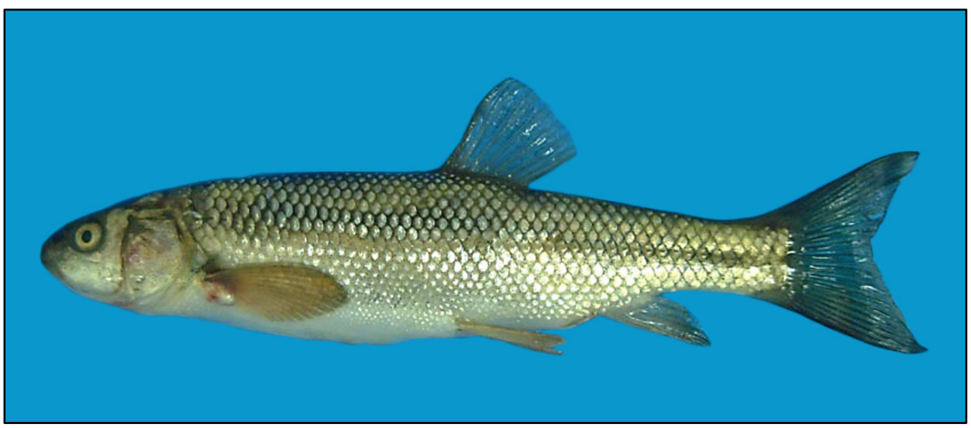
*Capoeta fusca*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Capoeta fusca*, 12.7 cm total length, ZISP 24034, South Khorasan, Mametabad in Zirkuh, after Berg (1949).



*Capoeta fusca*, ventral head, same as above.



*Capoeta fusca*, South Khorasan, Mehdi Abad, Birjand, Seyed Ali Johari.

*Capoeta fusca*, 12.4 cm standard length, North Khorasan, Qanat-e Segonbadan, Hari River basin, after Jouladeh-Roudbar *et al*. (2017).

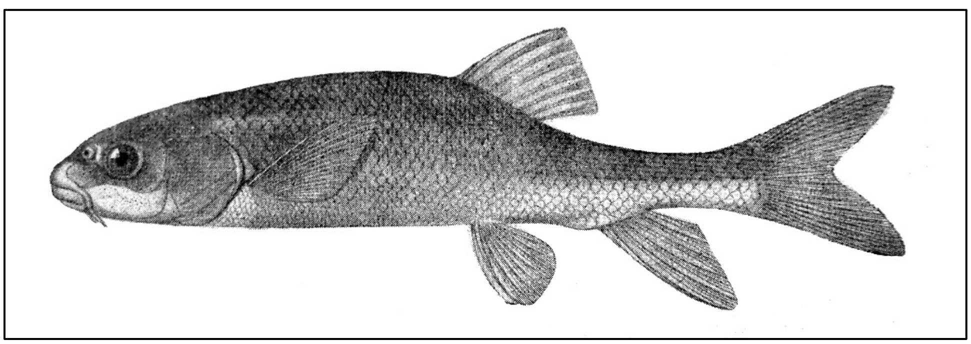
**Common names.** Siah mahi (= black fish), siahmahi-ye qanati (= qanat black fish), siyah mahi Kavir.

[Desert scraper, qanat barb or scraper].

**Systematics.** The two syntypes of *Capoeta fusca*, listed in Latin as from "Mondechi in Persia orientali", are in the Zoological Institute, St. Petersburg (ZISP 11108) and measure 121.9-172.9 mm standard length. Berg (1949) gave the locality in Russian as "Mondekhi, northern periphery of the Bajistan Salt Desert in southeast Khorasan". This locality is probably Mandehi or Miandehi at 34°53'N, 58°38'E. Nikol'skii (1897) listed a series of specimens in Latin, presumably all of which he regarded as types, *sic*:- "11108. Mondechi in Persia orientali. 12.IV.96 (2). 11109. Persia orientalis. 1896. (6). 11110. Persia orientalis. 1896. (5). 11111. Persia orientalis. 1896. 11112. Kuss in Persia orientali. 6.IV.96.", the last two lacking number of specimens. Berg (1949) gave 20 specimens for 11109, six specimens for 11110, and one specimen for each of the last two. Catalogue dates in ZISP for all these are 26.IV.96, presumably new style, while Berg (1949) gave new style dates 24.IV.1896 for the first and 18.IV.1896 for the last (and this last is 26.IV.1896 in the catalogue). Only ZISP 11108 specimens are regarded as syntypes by Berg (1949). Berg (1949) also pointed out the confusion over the date when Zarudnyi, the collector, was at "Kuss" (= Khusf at 32°46'N, 58°53'E) given by Nikol'skii as 6.IV.96 old style but on this date Zarudnyi was at "Kiaz-khak" near Asadabad (35°38'N, 59°21'E) south of Mashhad and only reached Khusf on 8 (or 20 new style).VI.96. This is not particularly critical in this instance but serves to point out the difficulties of reconciling literature, field notes, catalogues, and jar labels.

*Capoeta fusca*, syntype, ZISP 11112, Hamid Reza Esmaeili.

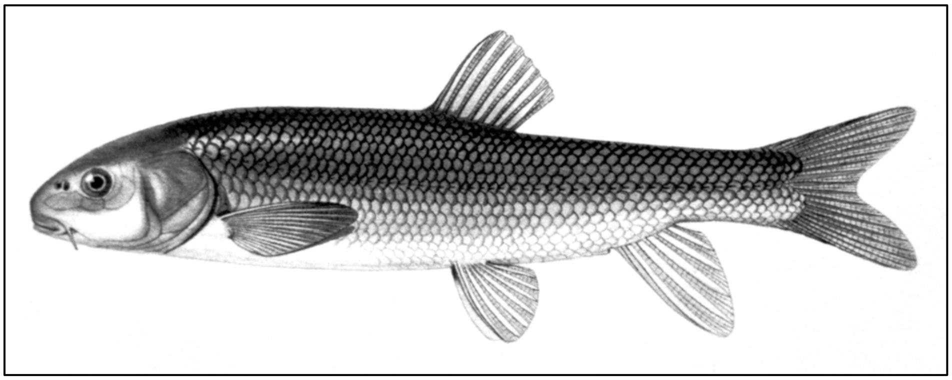
The types of *Capoeta gibbosa* Nikol'skii, 1897, a probable synonym, are in the Zoological Institute, St. Petersburg (ZISP 11104) but have dried at some point. Their locality was given by Nikol'skii in Latin as "Bochsani in Persia orientali". Kähsbauer (1963) gave a total length of 153 mm, presumably from only one specimen. This locality is given as "Bukhsani, southeastern Khorasan between Zirkuh and Khaf" by Berg (1949) and "SE Khorasan" by the *Catalog of Fishes* (downloaded 25 April 2020), as Bokhsani at 34°15'N, 60°04'E in Razavi Khorasan by Roselaar and Aliabadian (2007), and there is a Boqsani at 34°29'N, 60°03'E. The locality lies in the endorheic Namakzar-e Khvaf on the Afghan border south of the Hari river basin, one of several minor basins not separated on maps herein. Berg (1949) considered that this nominal species was close to *C. capoeta gracilis* but is distinguished by body proportions (longer caudal peduncle and a longer head) but it is founded on only two specimens, hardly an adequate sample. Jouladeh-Roudbar *et al*. (2020) and *Catalog of Fishes* (downloaded 2 May 2020) placed this species as a synonym of *C. capoeta*, presumably following Berg (1949), but that species is in northwestern Iran, remote from southeast Khorasan. Nikol'skii (1897) and Berg (1949) gave a dorsal fin branched ray count of 8 and lateral line scale counts of 47 (and also 55 in Berg) for the syntypes. The illustration of *C. gibbosa* in Berg (1949) has 7 branched rays, however. Kähsbauer (1963) gave a dorsal fin branched ray count of 8 and a lateral line scale count of 47 for *C. gibbosa*, presumably after Nikol'skii (1897). Nikol'skii (1897) also gave a dorsal fin branched ray count of 8 for *C. fusca* so the count for *C. gibbosa* may have included the last two unbranched rays now counted as one. The locality makes *C. gibbosa* a likely synonym of *C. fusca*. The dorsal fin ray count of 8 is anomalous for a *C. fusca* synonym but reservations on counts are outlined above. The scale count of *C. gibbosa* is found in both *C. fusca* and *C. heratensis*. There are two barbels in *C. gibbosa*. This taxon from an isolated basin warrants further investigation.



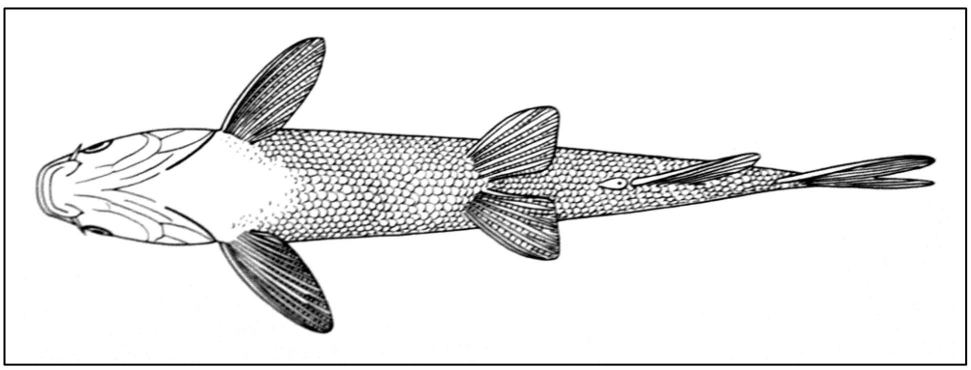
*Capoeta gibbosa*, syntype, 15.8 cm total length ZISP 11104, Eastern Khorasan, after Berg (1949).

*Capoeta fusca* var. *nudiventris* Nikol'skii, 1897 is a synonym. The syntypes are in the Zoological Institute, St. Petersburg (ZISP 11106) according to Berg (1949) and comprise three fish 92.4-121.5 mm standard length. Berg (1949) gave the type locality as "Zeride near Bajistan in southeast Khorasan, 30.IV.1896" (the date in the jar is 26.IV.1896). Nikol'skii (1897) listed three collections all from "Saride in Persia orientali. 18.IV.96." with numbers 11105, 11105 (presumably an error for 11106), and 11107 and six (actually seven in the jar and according to Berg (1949)), three, and five specimens respectively. Berg (1949) listed the five specimens under 11107 as from "Chakhak in the Al'kor region between Bajistan and Birjand. 9.V.1896", presumably at 33°17'N, 58°54'E. These five fish are 37.0-55.2 mm standard length, collected on 25.IV.1896 in the ZISP catalogue and not listed as types in the jar, nor in the

catalogue, nor in Berg (1949). The seven fish in ZISP 11105 measure 46.8-75.3 mm standard length, are from the same locality listed under ZISP 11106 in Berg (1949) and are listed as types in the ZISP catalogue, though not in Berg (1949). Judging from the labels and catalogue sheets, the types are probably from Sarideh at 34°22'N, 58°14'E and comprise 11105 and 11106.



*Capoeta fusca* var. *nudiventris*, 14.6 cm total length, ZISP 11106,
Zerid near Bajistan (= Bejestan) in southeastern Khorasan, after Berg (1949).



*Capoeta fusca* var. *nudiventris*, ventral view, as above, after Berg (1949).

Rainboth (1981) places both *fusca* and *nudiventris* in the genus *Schizocypris* on the basis of the enlarged scales around the vent and anal fin base, a condition reported on by Berg (1949) also but not considered by this latter author to warrant inclusion of these fish in *Schizocypris*.

Mohammadi *et al*. (2015) found populations showed variations in general morphology of otoliths, the sulcus shape and the shape of the dorsal and ventral rims. This variation was attributed to ecological conditions of the habitats. Banimasani *et al*. (2019) compared fish morphometrically from the Amirabad, Kalshur and Tabarak rivers of the Dasht-e Kavir and Hari River basins, finding differences between the three and the Kalshur fish (Kavir) separate from the other two (Hari).

**Key characters.** This species is distinguished from other large-scaled *Capoeta* species (60 or less lateral line scales) by having one pair of barbels, modally 7 dorsal fin branched rays, and a distribution in the Bejestan, Dasht-e Lut, Dasht-e Kavir, Hari River and Sistan basins.

**Morphology.** Some fish from isolated qanats are emaciated in varying degrees, or show an unusual body form presumably from inbreeding. The body is rounded and deepest over the pectoral fin, well in advance of the dorsal fin origin. The back in front of the dorsal fin

is gently convex or almost straight, in some falling more sharply just before the head. The caudal peduncle is compressed and shallow to moderate in depth. The snout is very short and is rounded. Some specimens have a deep groove across the snout before the nostrils, apparently unrelated to size. The rear of the eye is at the beginning of the anterior half of the head. The mouth is horseshoe-shaped in young and arched to almost straight in adults with a usually well-developed, sharp, horny edge. The moderately-thick mandibular barbel extends back to the anterior eye margin or the posterior half of the pupil. Rarely a specimen will have three barbels (e.g., CMNFI 2007-0023, 89.2 mm standard length, with an additional anterior left barbel). The last dorsal fin unbranched ray is weak with only a few fine denticles along the basal half. The dorsal fin margin is straight or weakly emarginate. The dorsal fin origin lies over or slightly anterior to the pelvic fin origin. The depressed dorsal fin does not reach back to a level with the anal fin origin. The caudal fin is moderately forked with pointed to rounded lobes, the lower lobe being more rounded. The anal fin has a rounded margin and falls short or reaches to the caudal fin base when appressed. The pelvic fins are rounded and do not extend back to the origin of the anal fin. The pectoral fins have a slightly convex margin and do not reach back to the origin of the pelvic fins. The pectoral fins have a slightly convex margin and do not reach back to the origin of the pelvic fins.

Dorsal fin with 3-4, modally 3, unbranched rays and 7-8, strong mode at 7, branched rays, anal fin with 3 unbranched and 5 branched rays, pectoral fin branched rays 14-20, and pelvic fin branched rays 7-9. Lateral line scales 40-62, mostly 46-56, predorsal scale rows 21-30, scales between dorsal fin and lateral line 8-10, and scales around caudal peduncle 17-26. Scales are found regularly arranged over the whole body, and are often enlarged around the anus and anal fin base. There is a pelvic axillary scale. Scales are oval and have a subcentral, markedly anterior focus, numerous radii on all fields and moderate numbers of circuli. Total gill rakers number 11-21, are short, and touch the raker below when appressed. Zareian *et al*. (2018) gave 11-15 total rakers in a key, 12-15 in the text, mode 12 (in the text, mode 13 in Table 9). My counts are mostly 14-17. The pharyngeal teeth are very spatulate up to the tip but are thick. There is an occasional trace of a fifth tooth in the major row but all the fish examined had only four strongly developed main row teeth. The gut is very elongate with several anterior and posterior loops. Total vertebrae number 40-43.

Some populations or individuals may show a very light belly extending up onto the lower flank rendering scales hard to see. *Capoeta nudiventris* was apparently founded on specimens like this. Some scales low on the flank are incompletely imbricate and deeply embedded in the skin. Berg (1949) in examining the types of *fusca* and *nudiventris* found the extent of the scales ventrally to be the same and *nudiventris* was not naked on the lower flank and belly.

Meristic values for Iranian specimens are:- dorsal fin branched rays 7(77), anal fin branched rays 5(77), pectoral fin branched rays 14(1), 15(1), 16(8), 17(23), 18(26), 19(13) or 20(5); pelvic fin branched rays 7(8), 8(64) or 9(5), lateral line scales 46(4), 47(6), 48(8), 49(10), 50(10), 51(9), 52(9), 53(9), 54(9), 55(2) or 56(1), predorsal scale rows 21(1), 22(1), 23(7), 24(9), 25(21), 26(18), 27(10), 28(4) 29(5) or 30(1), scales around caudal peduncle 17(1), 18(2), 19(6), 20(16), 21(25), 22(16) 23(9) or 24(2), total gill rakers 13(1), 14(11), 15(25), 16(26), 17(11), 18(1), 19(-) or 20(1), pharyngeal teeth 2,3,4-4,3,2(20), and total vertebrae 40(9), 41(42), 42(20) or 43(4).

Askari Hesni *et al*. (2020) examined five populations from the Dasht-e Lut basin and found differences in morphology and morphometry of the otolith and the urohyal bone.

**Sexual dimorphism.** A specimen 88.9 mm standard length (CMNFI 2008-0295, collection date unknown) bore largish tubercles under the eye and across the snout below the nostril level. Small scattered tubercles were on the top and sides of the head. Single tubercles were on scales of the back and upper flank, usually centred but some slightly off-centre, and on the lower flank from the dorsal fin level rearward. Not all scales bore tubercles in these areas so gaps were apparent and irregular. Large tubercles were present on the anal fin, most developed distally and posteriorly.

**Colour.** The back and flanks are dark to light brown or greenish while below the lateral line the body can be very light. Scales are outlined by pigment especially on the upper rear flank and back. The dorsal, anal and caudal fin membranes are often darker than the rays but the rays can be lined with pigment and so appear generally darker than the membranes, or pigment can be evenly spaced across the fin. Paired fins are yellowish and carry less pigment than other fins. Young fish may have a mid-lateral stripe as wide as the eye ending in an indistinct dark blotch on the caudal fin base. The peritoneum is dark brown to black.

**Size.** Reaches 21.5 cm total length (Johari *et al*., 2009).

**Distribution.** This species is found in eastern Iran in the Bejestan, Dasht-e Lut, Dasht-e Kavir, Hari River and Sistan basins, including many springs and qanats in these basins, not all named or easily located on maps - some are listed here and in the **Sources** below and see also the type localities discussed above. In the Bejestan basin from the Kalfarzaneh, Kalkhonik, Kalostekhani and Kalshur rivers; in the Dasht-e Kavir basin from the Aij-Shourab, Bidoaz or Bidvaz and Kalshur rivers; in the Dasht-e Lut basin from the Kardeh and Shur rivers, and the Abdolrahmati and Sharifabad qanats, Birjand; in the Hari River basin from the Amirabad, Kashaf and Tabarak rivers, and the Segonbadan River or qanat from Jouladeh-Roudbar *et al*. (2017) (but note the map locality is reversed with *C*. *capoeta* in the Lake Urmia basin); and in the Sistan basin generally in desert areas draining towards Sistan (Nikol'skii, 1899; Berg, 1949; Abdoli, 2000; Moshkani and Pourkasmani, 2004; Soltani *et al*., 2011; Ostovari *et al*., 2012; Jouladeh Roudbar *et al*., 2015; Alwan *et al*., 2016; Jouladeh-Roudbar *et al*., 2016, 2017; Zareian *et al*., 2018; Banimasani *et al*., 2019). Johari *et al*. (2009, 2010) recorded this species from the Afin, Asafshad, Gazdmoo, Ghoorghoori and Mardan Shah rivers in Qae'nat area and in 44 qanats of Birjand County in eastern Iran. Ostovari *et al*. (2011) recorded it from qanats of Ferdows City. Jouladeh-Roudbar *et al*. (2020) could not confirm its presence in the Sistan basin but this may depend on how that basin's limits are defined.

Some limited material below (seven fish) listed as *Capoeta cf*. *fusca* from the northern and western Dasht-e Kavir basin have 7 branched dorsal fin rays typical of *C*. *fusca* but 43-49 lateral line scales, 18-26 predorsal scales and 17-21 total gill rakers, characters overlapping with *C*. *aculeata*. Note also some of this material may have been selected by the collector (one or two specimens at each locality) and therefore not be representative of variation. This conflicting morphological data can be resolved with molecular data (see also table under *C*. *aculeata* for summary of ranges).

A record from the "Schalman Rud" presumably in the Caspian Sea basin is most probably an error (Wossughi, 1978).

**Zoogeography.** Saadati (1977) considered that this species entered eastern Iran from the west via the Namak Lake basin. See also above under the genus. Zareian *et al*. (2018) placed this species in the Aralo-Caspian group of *Capoeta* where it separated from *C*. *aculeata* 1.52 MYA.

**Habitat.** This species is found in rivers, streams, pools, springs, jubes (= irrigation

channels) and qanats. Karaman (1969a) considered that this species shows the greatest adaptation among *Capoeta* species to desert life: an elongate and low body, scaleless belly in many individuals, weak spiny dorsal fin ray, reduced number of dorsal fin rays, a short dorsal fin which can easily lie flat against the body, and the mouth structure.

Johari *et al*. (2008, 2009) studied 10 qanats in Birjand County and found the following ranges:- 3.8-24.9ºC, 0-6.3‰ salinity, 7.7-8.5 pH, 3.8-1,164 μS, 6.3-13.8 mg/l dissolved oxygen, 0.31-11.5 mg/l nitrate, 0-0.8 mg/l nitrite, 0.04-0.29 mg/l ammonia, 185-750 mg/l total hardness, 2.17-815 total dissolved solids, 25-410 mg/l calcium, 0-100 mg/l magnesium, 0.16-340 mg/l sulphate, 2.3-27 mg/l potassium, 0.01-0.14 mg/l chlorine and 0.2-0.95 mg/l phosphate. No mortalities were noted in fish kept in salinities up to 10‰ for 120 hours, but higher levels started to show progressive mortalities. As salinity increased, fish became darker and dead fish were almost black. The fish exhibited schooling behaviour both in aquaria and in their natural environment.

Teimori *et al*. (2017) investigated environmental variables using species distribution models, finding average rainfall, mean temperature and altitude to be important factors.

Habitat of *Capoeta fusca*, South Khorasan, Sharifabad Qanat, Birjand, Hamid Reza Esmaeili.

**Age and growth.** Johari *et al*. (2009) found a total length/weight relationship of body weight = $0.0101TL^{2.9477}$ for 600 fish from 10 qanats in Birjand County. Patimar and Mohammadzadeh (2011) examined 354 fish, 5.7-19.0 cm total length, from the Shadmehr qanat in South Khorasan and found a maximum age of $5^+$ years, negative allometric growth for males and isometric for females, males grew faster than females, and von Bertalanffy growth models $L_t = 18.74(1-e^{-0.33(t+0.473)})$ for males and $L_t = 22.35(1-e^{-0.32(t+0.333)})$ for females. Zareian *et al*. (2018a) gave a *b* value of 2.967 for 23 fish, 4.1-13.2 cm total length.

**Food.** Gut contents of the few fish examined contained fragments of large plants including large seeds, filamentous algae and sand grains. Johari *et al*. (2008, 2009) found this species in qanats of Birjand County to be herbivorous based on relative gut length and to be

relatively gluttonous based on gut vacuity index as did Ostovari *et al*. (2012) for Lut and Bejestan basin fish. Large plants and filamentous algae made up 86.8% of the food but molluscs, aquatic insects and frog eggs were secondary foods. Feeding was highest in December and January before spawning and in August and September when presumably productivity was greatest. In March to May, the spawning season, feeding was reduced. Badri Fariman *et al*. (2010) examined fish from the Birjand area and found a food preference of 86.6 for plant material and 13 for benthos.

**Reproduction.** Fish caught in April and May had mature eggs along with some immature eggs, indicating that spawning may occur in stages. Fish caught in November had small but obvious and developing eggs. Johari *et al*. (2008, 2009) found the reproduction period began in March and lasted until the latter part of May based on the gonadosomatic index. Patimar and Mohammadzadeh (2011) found a sex ratio of 1:2.42 in favour of females for their South Khorasan fish, with reproduction in the qanat between May and August with the gonadosomatic index highest for males in June and for females in July. Egg diameters attained 2.05 mm, maximum fecundity attained 22,773 eggs and relative fecundity up to 583 eggs/g. Badri Fariman *et al*. (2010) also found March to be the spawning time based on the gonadosomatic index, but with fry found at different lengths during all sampling times, spawning may occur more than once a year.

**Parasites and predators.** Black spots on the head and fins (syntypes of *nudiventris* as noted by Nikol'skii (1897)) were probably encysted larvae of trematodes (Berg, 1949). Johari *et al*. (2009) found the trematode *Clinostomum* in various body parts and their qanat fishes showed lordosis and scoliosis.

**Economic importance.** This species will feed on mosquito larvae under aquarium conditions and could have been a better candidate for combating malarial mosquitos than the exotic and deleterious *Gambusia holbrooki* (eastern mosquitofish).

**Experimental studies.** It has been studied in aquaria for the toxicity of lead acetate (Omidi *et al*., 2009). Toxicity decreased with increase in water hardness, qanat water with a high-water hardness (310 mg/l) showing low toxicity. Mansouri *et al*. (2011) found that cobalt accumulated in tissues of this species under experimental conditions, with liver showing the most and gills the fastest elimination. Mansouri *et al*. (2011, 2012) examined fish from qanats in the Birjand region for heavy metals (cadmium, chromium, cobalt, nickel and zinc) finding the highest levels in liver and lowest in gills and variations in levels between sample sites. All levels were acceptable in human health consumption terms. Accumulation was first in liver and last in skin and elimination was the reverse. Mansouri *et al*. (2012) studied fish from Birjand qanats determining levels of acute toxicity of mercury ($LC_{50}$ 96 h = 0.24 mg/l) and silver ($LC_{50}$ 96 h = 0.013 mg/l) and found that this species was very sensitive to silver. Mansouri *et al*. (2013) showed that this species has a potential for rapid accumulation and depuration of copper and could be used as a bioindicator for copper contamination. Mansouri *et al*. (2013) found fish from a Birjand qanat accumulated cobalt in the order liver>muscle>gill>skin while elimination was the reverse. Accumulation was rapid and increased with metal concentration in water and duration of exposure. Pourkhabbaz and Mohseni (2013) studied bioaccumulation and elimination of copper and found this followed the order gill>skin>muscle, so the gill was the critical organ for symptoms. Zarei *et al*. (2013) found the median $LC_{50}$ value for copper sulphate was 6.928 mg/l, mortality decreased with time, most deaths were in the first 24 hours, and behavioural changes increased with concentration. Sayadi *et al*. (2020) showed accumulation and elimination of zinc from zinc oxide nanoparticles in this species depended on

the tissue, exposure concentration and duration, and was dependent on the presence of graphene nanosheets.

**Conservation.** A widely distributed species apparently able to survive in a wide range of minimal desert habitats, it may not be in need of conservation. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern even though severe drought has occurred through its range. It has numerous populations with relatively high numbers of fish.

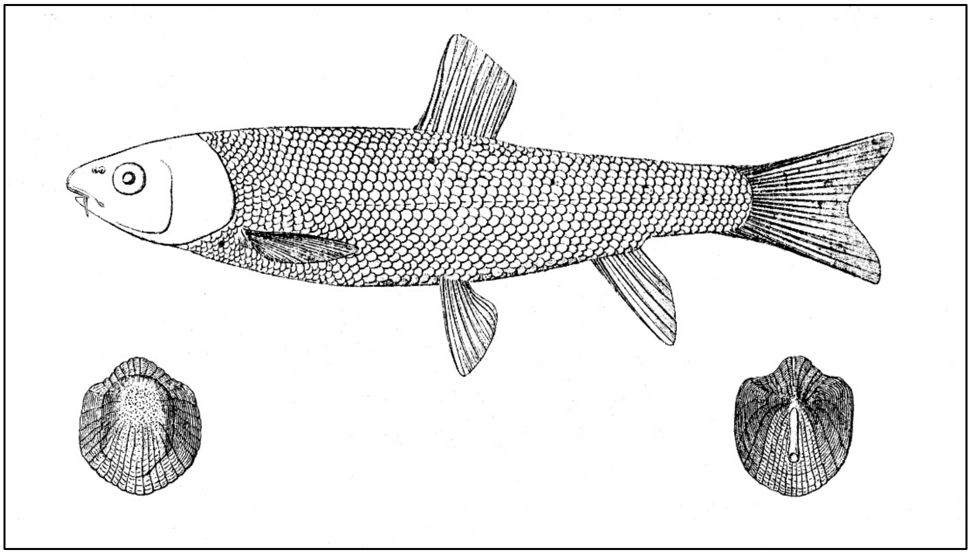
**Sources.** Type material:- *Capoeta fusca* (ZISP 11108) and *Capoeta nudiventris* (ZISP 11105 and ZISP 11106).

Iranian material:- CMNFI 2002-0202, 1, 136.9 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2007-0015, 8, 60.1-85.6 mm standard length, Razavi Khorasan, qanat at Khalaj (ca. 34º54'N, ca. 58º52'E); CMNFI 2007-0016, 8, 85.5-171.4 mm standard length, Razavi Khorasan, qanat and jube at Bidokht (ca. 34º21'N, ca. 58º46'E); CMNFI 2007-0017, 3, 26.8-81.1 mm standard length, South Khorasan, qanat at Dasht-e Bayaz (ca. 34º02'N, ca. 58º47'E); CMNFI 2007-0018, 15, 21.7-92.4 mm standard length, South Khorasan, Shur River (ca. 33º52'N, ca. 59º41'E); CMNFI 2007-0019, 9, 32.7-141.3 mm standard length, South Khorasan, qanat between Esfideh and Abbasabad (ca. 33º29-39'N, ca. 59º38-46'E); CMNFI 2007-0020, 23, 43.7-115.1 mm standard length, South Khorasan, qanats at Marak and Rabi'an (ca. 32º55-58'N, ca. 59º26-27'E); CMNFI 2007-0021, 16, 24.8-56.3 mm standard length, South Khorasan, Shah Abbas qanat in Asadabad (32º55'N, 60º01'E); CMNFI 2007-0022, 6, 56.7-112.1 mm standard length, South Khorasan, qanat pool at Mud-e Dahanab (32º43'N, 59º31'E); CMNFI 2007-0023, 6, 82.5-113.1 mm standard length, South Khorasan, qanat at Sarbisheh (32º34'N, 59º48'E); CMNFI 2007-0024, 23, 26.5-92.3 mm standard length, eastern Iran (no other locality data); CMNFI 2008-0193, 1, 146.8 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0194, 1, 138.5 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0195, 1, 127.3 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0196, 1, 127.4 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0197, 1, 75.4 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0198, 1, 122.3 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0201, 1, 111.8 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0202, 1, 135.6 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E).

*Capoeta cf. fusca*:- CMNFI 2008-0295, 1, 88.9 mm standard length, Semnan, qanat at Chagam (35º49'N, 55º08'E); CMNFI 2008-0296, 1, 85.2 mm standard length, Semnan, qanat at Gahanabad (36º46'N, 56º00'E); CMNFI 2008-0297, 2, 91.5-96.2 mm standard length, Semnan, qanat at Gahanabad (36º46'N, 56º00'E); CMNFI 2008-0299, 1, 76.5 mm standard length, Semnan, qanat at Bidestan (35º17'N, 54º44'E); CMNFI 2008-0301, 1, 67.2 mm standard length, Tehran, qanat at Bakhshabad (35º33'N, 53º05'E); CMNFI 2008-0302, 1, 71.5 mm standard length, Semnan, qanat at Chahbagher (no other locality data).

## *Capoeta gracilis*

(Keyserling, 1861)



*Capoeta gracilis*, with normal and lateral line scales, after Keyserling (1861).

**Common names.** Siyah mahi Esfahan.

[Esfahan scraper].

**Systematics.** *Scaphiodon gracilis* was described from "Wasserleitung bei Gaes, einige Meilen von Isphahan" (a canal near Gaz a few miles from Esfahan - Wasserleitung may also be translated as water conduit and aqueduct and may have been referring to a qanat stream as canals in the European sense were not then present in Iran). Gaz is at 32º48'N, 51º37'E. No types were kept. In the original description, *C. gracilis* referred to specimens with black and white parallel stripes extending along the flanks, but molecular results placed both specimens with and without these parallel lines in the same clade (Zareian *et al*., 2018) but see below.

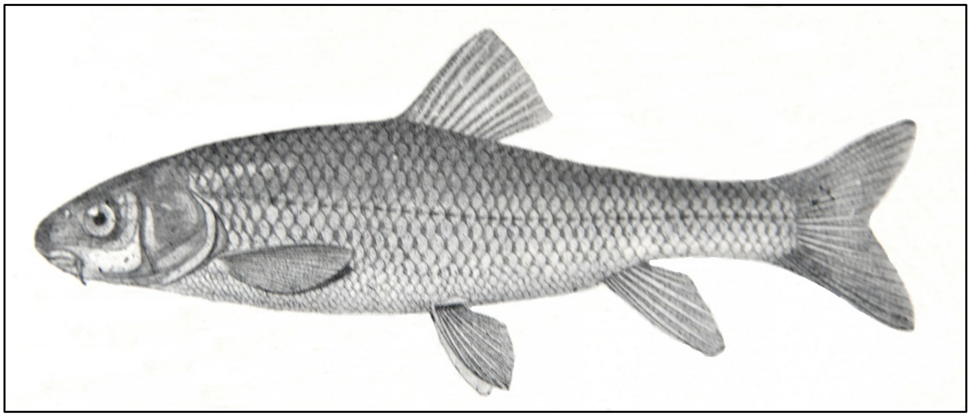
*Capoeta gracilis* Temminck and Schlegel, 1846 was described from Japan making *C. gracilis* Keyserling, 1861 a junior homonym. However, the former is now placed in the genus *Squalidus* and the junior homonym has never been replaced, is valid and no replacement name is needed (Zareian *et al*., 2018).

*Capoeta capoeta gracilis* or *Capoeta gracilis* were the names used for fish in the Caspian Sea basin in particular (now *C. razii* for most of that basin) with *C. capoeta* in the Aras River basin and the Lake Urmia basin.

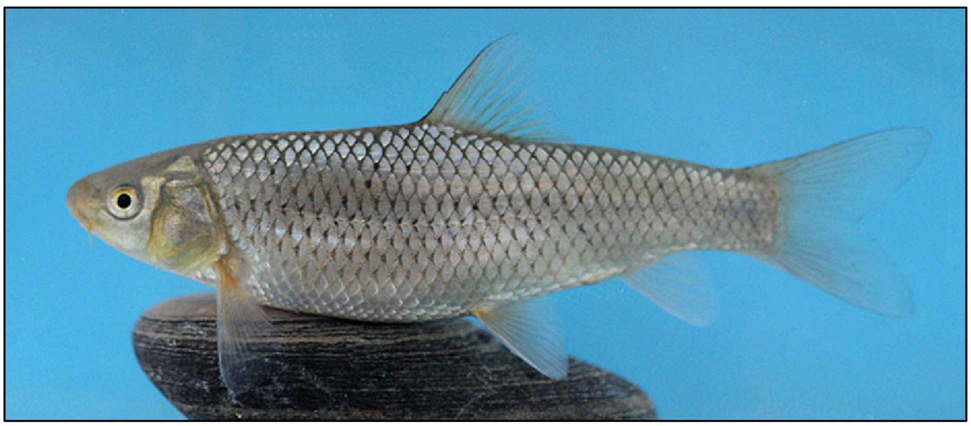
The original description and the line drawing in Keyserling (1861) both have 55 total lateral line scales (so about 53 to the hypural fold). *Capoeta* material seen by me from the Esfahan basin therefore falls into three groups based on lateral line scale counts to the hypural fold, namely 51-60 and presumably *C. gracilis*, 68-84 and presumably *C. coadi*, and those with 32-46 being similar to *C. aculeata* and/or *C. macrolepis* but distinguished by DNA evidence from these two species and therefore presumably an unnamed new species. Meristic data in various papers along with illustrations refer to these fish with lower scale counts as *C. gracilis* but they are probably the putative new species (e.g., see illustrations below, Zareian *et al*. (2018) and Jouladeh-Roudbar *et al*. (2020)). Combining the two lower and discrete sets of counts for the lateral line scales gives 32-60, a very wide range and unlikely for a single, large-scaled species. It is possible that *C. gracilis* is founded on a hybrid between a large-scaled species and a small-scaled species but new material is needed for DNA work to verify this, or to separate and define such material with 51-60 lateral line scales from other *Capoeta* species in the Esfahan basin. Material examined by Zareian *et al*. (2018) from the Esfahan basin and

assigned to *C. gracilis* had 32-46 lateral line scales and were distinguished from all other species in the *Capoeta capoeta* species group by having two fixed, diagnostic nucleotide substitutions in the mtDNA cytochrome *b* and one in the COI regions. The modern specimens with a lateral line scale count of 51-60 are unlikely to be an introduced species since Keyserling (1861) found similar material.

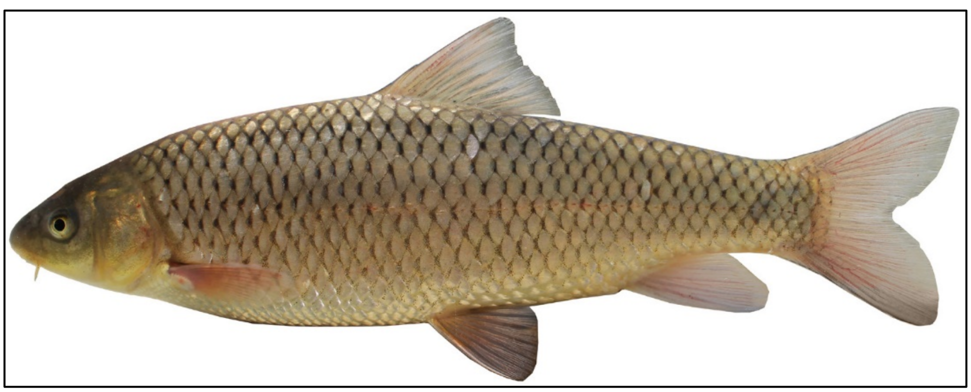
The following illustrations show fish with lateral line scale counts in the lower range and are presumably of the putative new species.



*Capoeta macrolepis* (*sic*), 13.5 cm total length, ZISP 24355,
Esfahan, near Esfahan, after Berg (1949).



*Capoeta gracilis* (*sic*), Esfahan, Zayandeh River at Geshnizjan, Hamid Reza Esmaeili.



*Capoeta gracilis* (*sic*), Esfahan, Zayandeh River, after Jouladeh-Roudbar *et al*. (2020).

Note that *C. fusca*, potentially present in the Esfahan basin, has a wide range of lateral line scales (40-62, mostly 46-56) but is found predominately on the northern and eastern fringes of the central deserts while the Esfahan basin is on the western fringe, and has a strong mode of 7 branched dorsal fin rays and 11-21 total gill rakers (versus 8 and 18-25 for *C. gracilis* and the putative new species).

Moghadamnia *et al*. (2015a, 2015b) found differences in snout and head length but no clear differences between scale structures from fish identified as *C. aculeata* (either *C. gracilis* or the putative new species) up- and down-stream of the Zayandeh River Dam, attributed to trophic differences between two different habitats.

References to age and growth and parasites for fish identified as *C. gracilis*, *C. capoeta* and *C. aculeata* in the Esfahan basin could be the former or the putative new species.

**Key characters.** This species is distinguished from other large-scaled *Capoeta* species by having one pair of barbels, modally 8 dorsal fin branched rays, 51-60 lateral line scales, and a distribution in the Esfahan basin. A lower lateral line scale count of 32-46 for some fish probably distinguishes another taxon in the Esfahan basin as noted above.

**Morphology.** The following description is based on fish with 51-60 lateral line scales and Keyserling (1861). The body is rounded and slender and deepest at the dorsal fin origin. The predorsal profile is gently convex. There is some evidence of a keel near the dorsal fin origin. The caudal peduncle is compressed and deep. The snout is rounded. The eye lies in advance of the half-way point of the head. The mouth is subterminal and the lower jaw is a shallow curve with a horny edge. The upper lip is thick and the snout partially overlaps it. The barbel is thick at the base but tapers rapidly in some fish, or is mostly thick. The barbel extends back to the nostril or to the eye. The dorsal fin has a moderate spine with 20-22 medium denticles extending half way to two-thirds along the spine, and the remainder of the spine tapers distally. The dorsal fin margin is emarginate to straight. The dorsal fin origin is anterior to the level of the pelvic fin origin. The depressed dorsal fin does not extend back level with the anal fin origin. The caudal fin is shallowly to moderately forked with rounded tips, especially the ventral tip. The anal fin margin is rounded and the fin does not extend back to the caudal fin base. The pelvic fin is rounded and does not extend back to the anal fin origin. The pectoral fin is rounded and does not extend back to the pelvic fin origin.

Dorsal fin unbranched rays 3-4, branched rays 7-8, usually 8, anal fin unbranched rays 3, branched rays 5, pectoral fin branched rays 18-21, pelvic fin branched rays 9-10, lateral line scales 51-60, scales at beginning of lateral line above pectoral fin small and not obvious, scales above lateral line 9-11, scales around caudal peduncle 20-23, and total gill rakers 18-23, the longest touching the second raker below when appressed. There is a well-developed pelvic axillary process. Scales on the belly and breast are the smallest. Scale shape is squarish with a rounded posterior margin, straight to gently rounded dorsal and ventral margins, and anterior margin rounded or with a central protrusion and gentle indentations above and below. There are evident and abrupt anterior scale corners but these are very rounded. There are numerous fine circuli, a subcentral anterior focus, and radii on all fields, being numerous on the anterior and posterior fields but few and curved laterally. Pharyngeal teeth are 2,3,4 or 5-5 or 4,3,2 with the fifth tooth when present a nub, and are scalloped with flattened, curved crowns. Total vertebrae number 44-45. Note vertebral counts are higher and match scale counts compared to the other putative species in the Esfahan basin.

Meristic values are:- dorsal fin branched rays 7(1) or 8(8), anal fin branched rays 5(9), pectoral fin branched rays 17(1), 18(2), 19(1), 20(4) or 21(1), pelvic fin rays 9(7) or 10(2),

lateral line scales 51(1), 52(-), 53(1), 54(-), 55(-), 56(2), 57(2), 58(1), 59(1) or 60(1), total gill rakers 18(1), 19(-), 20(2), 21(3), 22(-) or 23(2), and total vertebrae 44(1) or 45(6).

The following description is based on fish with 32-46 lateral line scales and distinctive DNA characters, a putative new species (see above and Zareian *et al*. (2018)). The body is rounded and moderately compressed and the greatest body depth is anterior to, or at, the origin of the dorsal fin. The predorsal profile is slightly convex to straight, and the ventral profile is straight or slightly convex. The caudal peduncle is compressed and moderately deep. The dorsal head profile is slightly convex. A groove may be present across the head in front of the nostrils in some fish. The mouth is inferior, small, transverse and almost straight but is u-shaped in young. The lower jaw is covered by a well-developed horny sheath, with a sharp edge. Lips are thin, being thickest at the corners. The rostral cap is well-developed, partly overlapping the upper lip. Only maxillary barbels are present, reaching back to the anterior margin of eye or past it, or can rarely be reduced to stubs. The eye lies in advance of the beginning of the anterior half of the head. The dorsal fin spine fin is moderately thickened and denticles are long and narrowly spaced. The dorsal fin margin is almost concave or slightly straight. The dorsal fin origin is slightly to obviously in front of a vertical through the pelvic fin origin. The caudal fin has a shallow fork with pointed to rounded tips, the lower lobe more evident. The anal fin has its margin almost convex or rounded and does not reach back, or almost does, to the caudal fin base when depressed. The pelvic fin has a rounded tip and reaches back to about 50-80% of the distance between the pelvic fin tip and the anal fin origin when depressed. One specimen had the left pelvic fin absent (CMNFI 1979-0090). The pectoral fin has a rounded tip and reaches back to about 50-65% of the distance between the pectoral and pelvic fin origins when depressed.

Dorsal fin with 3-5, modally 4, unbranched rays and 7-8 (modally 8) branched rays, anal fin with 3 unbranched and 5 branched rays, pectoral fin with 15-19, modally 17 branched rays, and pelvic fin with 8-9, modally 8, branched rays. Lateral line complete, with 32-46, modally 42, scales, scales at beginning of lateral line above pectoral fin large and obvious, scale rows between dorsal fin origin and lateral line 6-8, modally 7, scale rows between anal fin origin and lateral line 5-6, modally 6, scale rows between lateral line and pelvic fin origin 5-7, modally 6, and scales around caudal peduncle 6-9, modally 9 (presumably for only half of the caudal peduncle and excluding one or two lateral line scales). A pelvic axillary process is comprised of 2-3 scales. Scale shape is rectangular to squarish with a rounded posterior margin, somewhat wavy in some fish, the dorsal and ventral margins are straight to slightly rounded, and the anterior margin has a central protrusion weakly or strongly indented above and below, or the whole anterior margin is wavy. The anterior scale corners are abrupt but rounded. There are numerous fine circuli, a subcentral anterior focus, and few to moderate numbers of radii present on the anterior and posterior fields, with some fish having a few curved lateral radii. Total gill rakers number 20-25, modally 23, and the depressed raker reaches the second raker below. Pharyngeal teeth are 2,3,4 or 5-5 or 4,3,2 with the fifth tooth sometimes reduced to a nub, and are scalloped with flattened, curved and narrow crowns. Total vertebrae number 39-42.

Meristic values are:- dorsal fin branched rays 7(1) or 8(1), anal fin branched rays 5(2), pectoral fin branched rays 17(1) or 18(1), pelvic fin rays 9(2), lateral line scales 40(1) or 41(1), total gill rakers 23(1) or 24(1), and total vertebrae 42(2).

**Sexual dimorphism.** The form with 51-60 lateral line scales (22 May 2007, CMNFI 2008-0289) has large tubercles between the eye and the snout under the nostril, with smaller

tubercles scattered on the operculum. Small tubercles are found on top of the head. Upper flank scales and scales over the anal fin have 1-3 small tubercles scattered on each scale. The anal fin rays bear small to moderate tubercles distally. Small horny tubercles may occur around the head region and on all fins in the form with 32-46 lateral line scales (Zareian *et al*., 2018).

**Colour.** Preserved specimens of the form with 51-60 lateral line scales have the following pigmentation. Overall colour can be brown and quite dark, even on the belly, or fish can be overall lighter with scales outlined by pigment and a pale yellowish belly. There are occasional small flank blotches. All fins are dark and fin rays may be darker than the membranes or, in lighter fish, the dorsal and anal fin membranes are darker. The caudal fin has a pale margin. Keyserling (1861) reported on live fish as being yellowish with the head and back very dark brown, fins reddish, and isolated black spots present on the fins and body. The peritoneum was recorded as black.

Live specimens of the form with 32-46 lateral line scales have the back grey to blackish or green-brown, or golden olive-green in smaller individuals. The upper flanks are darker than the lower, and the belly and lower flank are yellow up to the lateral line with the median area of the belly white. Some smaller fish have small black spots or blotches on the sides and fins and a caudal peduncle blotch (and sometimes parasites causing fin-spotting). The flanks have some light and dark stripes along the lateral line. The anterior base of the scales on the back and flanks are highly pigmented and scales are usually outlined by pigment. The sides of the head are golden brown or golden gray. Fins are often yellowish-brown or dirty green, although the dorsal and caudal fins are darker than the others, and all fins are relatively transparent. There is a yellowish spot at the base of the pectoral and pelvic fins. Preserved fish have pigment on the rays and membranes of fins without any distinctive pattern. The dorsal and caudal fins are darker than the anal, pelvic and pectoral fins. The iris is golden to orange and the upper part of the iris is darker than the lower. The peritoneum is black.

**Size.** Attains 23.9 mm standard length for the form with 51-60 lateral line scales and 16.1 cm standard length for the form with 32-46 lateral line scales.

**Distribution.** The form with a scale count of 51-60 is found in the Esfahan basin in the Zayandeh River, the Daran River basin, the Gav Khuni, and at the type locality (see above). Fish with a lateral line scale count of 32-46 are found in the Esfahan basin in the Doran (presumably Daran), Pelasgan and Zayandeh rivers (Zareian *et al*., 2018).

**Zoogeography.** Zareian *et al*. (2018) placed this species (as the form with a lateral line scale count of 32-46) in the Aralo-Caspian group of *Capoeta*, where it separated from *C. macrolepis* 1.16 MYA.

**Habitat.** The form with a lateral line scale count of 51-60 is found in rivers, streams, qanats and canals (*sic*, presumably qanats) and limited collection data included a temperature of 17ºC, pH 6.2, conductivity 0.5 mS, river width 4 m (and much wider for the Zayandeh River), slow to medium current, pebbles, sand or mud bottoms, encrusting vegetation, and a grassy shore. The form with a lateral line scale count of 32-46 is found in streams and rivers and limited collection data included a temperature of 17ºC, pH 6.2, conductivity 0.4-0.55 mS, river width 4-80 m, slow to fast current, clear or cloudy water, pebbles, sand or mud bottoms, encrusting vegetation, and a grassy shore.

**Age and growth.** Zareian *et al*. (2018a) gave a *b* value of 3.126 for 31 fish identified as *C. gracilis* and presumably the putative new species, 7.1-13.0 cm total length.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** Williams *et al*. (1980) reported the helminths *Khawia armeniaca* (a cestode) and *Acanthocephalorhynchoides cholodkowskyi* (an acanthocephalan) from fish identified as *C. capoeta* in the Zayandeh River at Esfahan, possibly the putative new species. Masoumian *et al*. (2007) recorded the myxosporean parasite *Myxobolus cristatus* from fish identified as *C. aculeata* but possibly the putative new species in the Zayandeh River. Mehdipoor *et al*. (2004) recorded the monogeneans *Dactylogyrus chramuli*, *D. gracilis* and *D. lenkorani* in fish identified as *C. aculeata* but possibly the putative new species in the Zayandeh River. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Pallisentis cholodkowskyi* from the Zayandeh River in fish identified as *C. aculeata* but possibly the putative new species.

**Economic importance.** None.

**Experimental studies.** None.

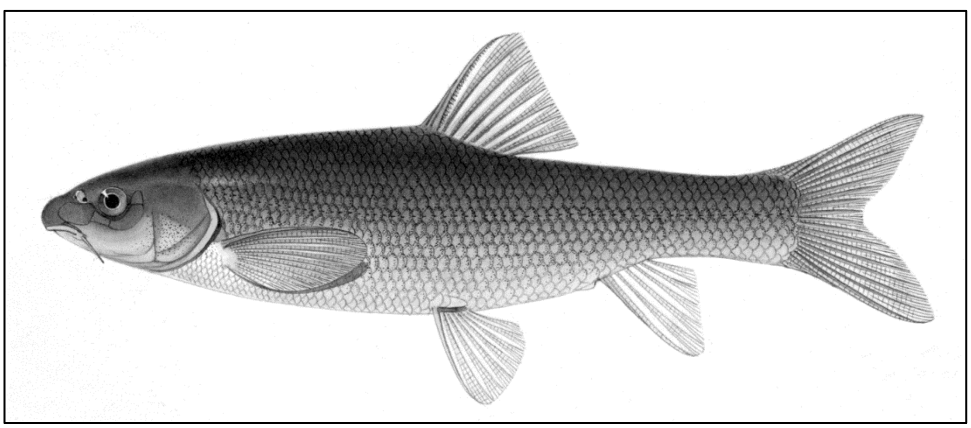
**Conservation.** Jouladeh-Roudbar *et al*. (2020) listed it as Vulnerable (as *C. gracilis* but based on form with 32-46 lateral line scales) through habitat loss and agricultural and industrial pollution. This would presumably apply to all *Capoeta* species in the Esfahan basin.

**Sources.** Based in part on Keyserling (1861) and Zareian *et al*. (2018).

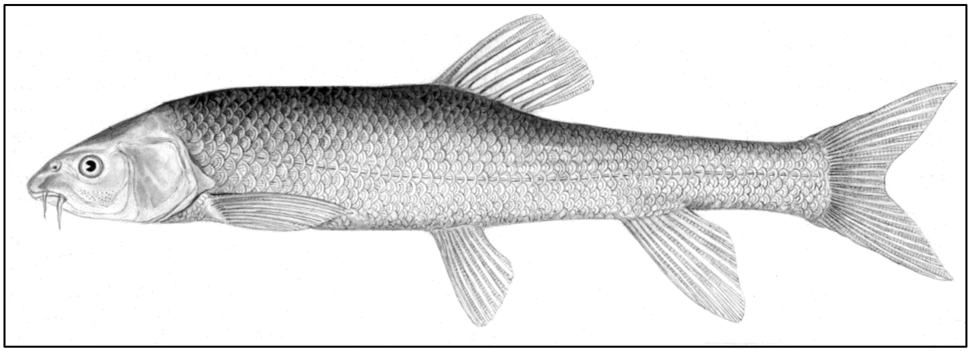
Iranian material:- Fish with a lateral line scale count of 51-60: CMNFI 1979-0251, 3, 32.2-42.9 mm standard length, Esfahan, stream 1 km east of Daran (32º59'N, 50º26'E); CMNFI 2008-0289, 6, 179.0-238.8 mm standard length, Esfahan, central Zayandeh River (32º45'43"N, 51º54'30"E); CMNFI 1979-0090, 2, 153.6-160.5 mm standard length, Esfahan, Gav Khuni (ca. 32º21'N, ca. 52º49'E). Fish with a lateral line scale count of 32-46: CMNFI 1979-0243, 2, 25.1-32.4 mm standard length, Esfahan, Zayandeh River at Falavarjan (32º33'N, 51º31'E); CMNFI 1979-0251, 47, 23.2-42.4 mm standard length, Esfahan, stream 1 km east of Daran (32º59'N, 50º26'E).

## *Capoeta heratensis*

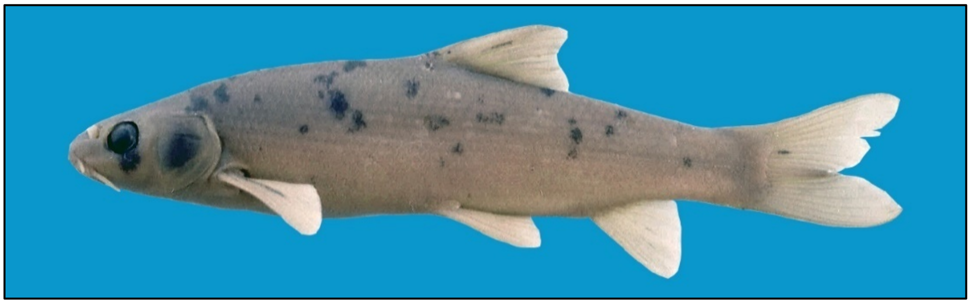
(Keyserling, 1861)



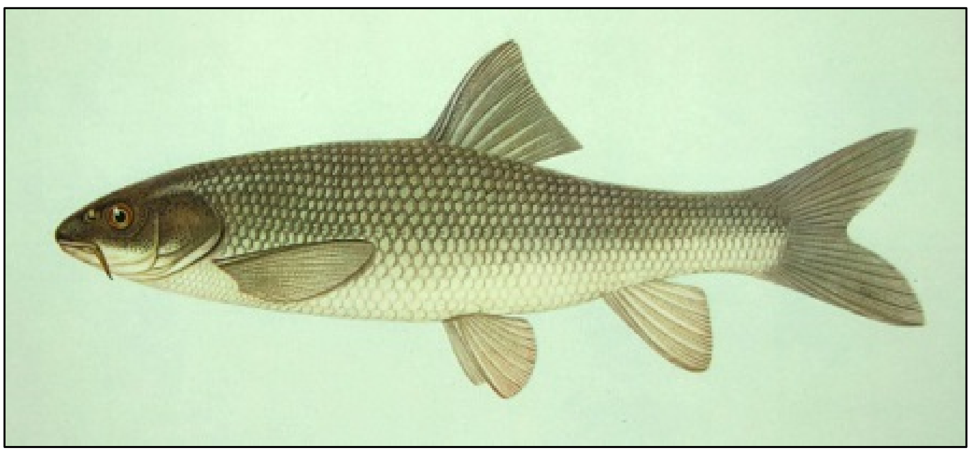
*Capoeta heratensis*, 14.8 cm total length, ZISP 11120, Turkmenistan, Germab River, after Berg (1948-1949).



*Capoeta heratensis* morpha *elongata*, 29.7 cm total length, ZISP 10358, Turkmenistan, Tedzhen River, after Berg (1948-1949).



*Capoeta heratensis*, Iran, Hari River basin, Keyvan Abbasi.



*Capoeta heratensis*
(CC0, NOAA Photo Library, N. N. Kondakov).

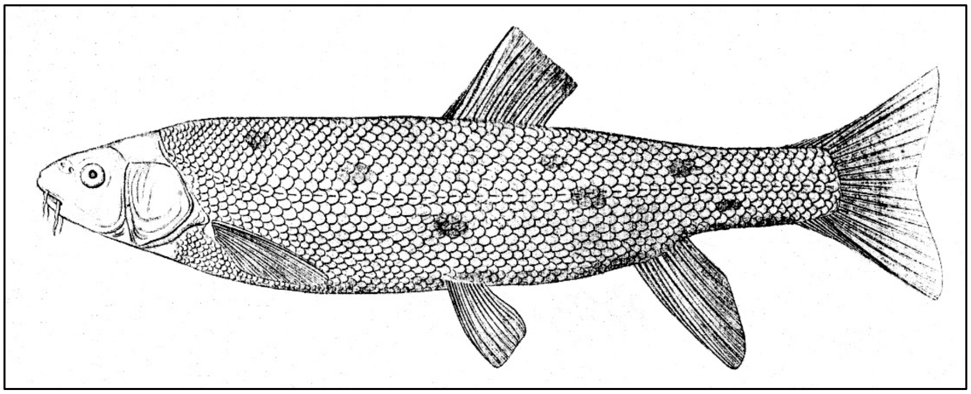
**Common names.** Siyah mahi Harat or Herat, siah mahi Herati.

**[**Shir mahi (meaning milk fish) and possibly khal mahi (or moi in Hazara from Shank (2007)); Transcaucasian barb, Transcaspian khramulya in Russian (also marinka is used locally but this is an error); Hari or Herat scraper].

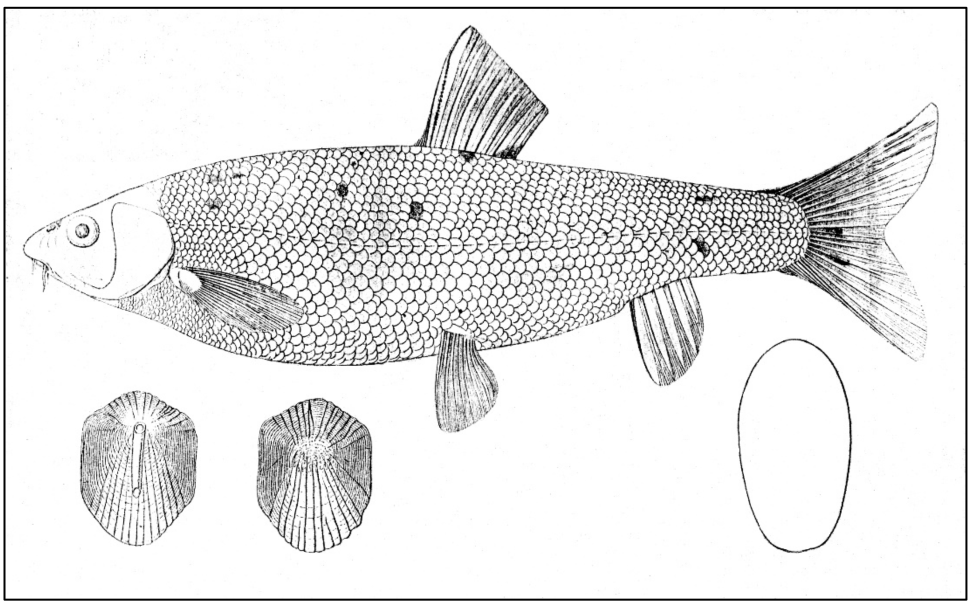
**Systematics.** Reshetnikov and Shakirova (1993) listed *Capoeta heratensis* as a full species. A hybrid of *Capoeta heratensis* and *Schizothorax pelzami* was reported from the northern Kopetdag in Turkmenistan (Starostin, 1936). *C. heratensis* shows major variations in body form, sometimes called morpha *elata* with a deep body and morpha *elongata* with a shallow and elongate body where body depth is less than head length. These are not taxonomically significant but simply ecomorphs and all intermediates between the two

extremes can be found. The deep-bodied form *elata* probably formed part of the fishes described as *asmussii* (Berg, 1948-1949). Eagderi *et al*. (2017) found differences between Aal, Bidvaz and Hari river populations using a geometric morphometric technique. The Bidvaz population showed greater differences compared to the two other populations. The observed differences were attributed to the diversity of habitats and feeding habits of the studied populations as well as geographical separation.

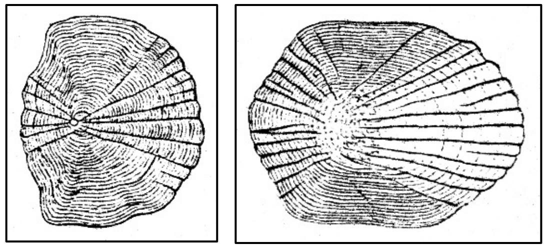
There is no type material of *Scaphiodon heratensis* or of its synonym *Scaphiodon asmussii* Keyserling, 1861. *S. heratensis* was described from the "Heri-Rud, ein Fluss bei Herat" and *S. asmussii* from "Warme Quelle bei Sultan Karaul, 8 Meilen nordöstlich von Herat" (both now in Afghanistan, formerly in Persia).



*Scaphiodon heratensis*, after Keyserling (1861).



*Scaphiodon asmussii*, after Keyserling (1861_



*Scaphiodon heratensis* and *Scaphiodon asmussii*,
flank scales, after Keyserling (1861).

**Key characters.** This species is distinguished from other large-scaled *Capoeta* species (60 or less lateral line scales) by having two pairs of barbels, and a distribution in the Dasht-e Kavir and Hari River basins.

**Morphology.** This species has a rounded body with a straight, to gently arched, dorsal profile in front of the dorsal fin to the snout. The body is deepest at the dorsal fin origin or slightly in advance. The caudal peduncle is moderately compressed and of average depth. The snout is short, rounded and there is a rostral fold over the upper lip but not obscuring it. The eye is in the anterior half of the head. The mouth is subterminal and u-shaped in young and a shallow arch with a horny edge in adults. The anterior barbels are thin and the posterior barbels thick. The anterior barbels do not reach the anterior eye margin, and the posterior ones reach mid-eye or just beyond. Young fish up to 2.5 cm lack barbels (Berg, 1948-1949). The dorsal fin spine is moderate, thick at the base and tapering rapidly. The denticles are of medium to relatively large size and the last third to a fifth of the spine has no denticles. The dorsal fin margin is straight to slightly emarginate and the dorsal fin origin is slightly to obviously anterior to the level of the pelvic fin origin. When depressed the dorsal fin does not extend back to the anal fin origin level. The anal fin margin is rounded and the fin does not extend back to the base of the caudal fin or almost reaches it. The caudal fin is moderately forked and the fin tips are rounded to pointed. The pelvic fin margin is rounded and the fin tip is remote from the anus. The pectoral fin margin is rounded and the fin tip is remote from the origin of the pelvic fin.

Dorsal fin with 3-4 (modally 3) unbranched and 7-9 (modally 8) branched rays, anal fin with 3-4 unbranched and 5-6 (modally 5) branched rays, pectoral fin with 16-19 (modally 17) branched rays, and pelvic fin with 7-8 (modally 8) branched rays. Lateral line scales 46-60 (modally 56-57), scales around the caudal peduncle 9-11 (presumably only half the caudal peduncle and perhaps excluding one or two lateral line scales - my counts are 21-24), scale rows between the dorsal fin origin and the lateral line 9-12 (modally 10), scale rows between the anal fin origin and the lateral line 7-8 (modally 7), and scale rows between the origin of the pelvic fin and the lateral line 7-9 (modally 9). A pelvic axillary scale is present. Scales have parallel or slightly rounded dorsal and ventral margins, the posterior margin is rounded (or wavy in some fish) and protruding and the anterior margin is centrally rounded and protruding and flanked by concavity on each side, or rounded, or wavy. The focus is subcentral anterior. Radii are numerous on the anterior and posterior fields, few to none on the lateral fields. There are many fine circuli. Gill rakers number 16-25, possibly including lower arch counts only, and are thin and weak. Pharyngeal teeth are spatulate but not all teeth were ossified and countable. Gut length is 7-13 times body length (Gabrielian, 1998). Total vertebrae number 40-43 (Jouladeh-Roudbar *et al*., 2020).

Meristic values for Iranian specimens are:- dorsal fin branched rays 7(3) or 8(2), anal

fin branched rays 5(5), pectoral fin branched rays 16(1), 17(2), 18(-) or 19(2), pelvic fin rays 7(1) or 8(4), lateral line scales 54(1), 55(1) …. 58(2) or 59 (1), and total gill rakers 24(2) or 25(1).

**Sexual dimorphism.** Males bear moderately large tubercles on the head in front of the eye to the upper lip below the nostril level. Smaller tubercles are present on top of the head and on the anterior flank and back scales, 1-2 per scale near the margin or centrally on the scale. There are 1-3 tubercles on scales above the anal fin. Large tubercles are present distally and on posterior rays of the anal fin (CMNFI 1993-0138, 129.5 mm standard length caught on 11 June 1992).

**Colour.** The dorsal head and upper part of the flank are golden brown, the ventral head and belly white to silvery. The flank may have dark, irregular spots and the back and flank may be dark. The operculum is golden-yellow. The pectoral and pelvic fin bases are dark orange and the leading edge of the pelvic fin may be pale. The iris is white to golden yellowish.

**Size.** Attains 45.0 cm total length and 1.5 kg (Gabrielian, 1988).

**Distribution.** This species is found in the Dasht-e Kavir basin, and in the Hari River basin (= Tedzhen River basin) in Afghanistan, Iran and Turkmenistan. In Iran, it is recorded from the Dasht-e Kavir basin in the Bidvaz River; and in the Hari River basin in the Aal, Akhland, Hari, Jam, Kalat, Kardeh, Kashaf and Zanglu rivers, Gilas Spring, Kuh-e Sang Park in Mashhad, Bazangan Lake, and the Dousti and Kardeh dams (Yazdani-Moghaddam *et al*., 2015; Alwan *et al*., 2016; Abbasi *et al*., 2016; Eagderi *et al*., 2017; Jouladeh-Roudbar *et al*., 2016, 2017, 2020; Asgharnia *et al*., 2018; Zareian *et al*., 2018).

Also recorded from the Karakum Canal and Kopetdag Reservoir in Turkmenistan (Shakirova and Sukhanova, 1994; Sal'nikov, 1995) and may eventually reach Iranian waters in the Caspian Sea basin.

**Zoogeography.** Zareian *et al*. (2018) placed this species in the Aralo-Caspian group of *Capoeta* where it diverged about 2.36 MYA.

**Habitat.** This species is found in rivers, streams, lakes, pools, dams, springs and qanats.

**Age and growth.** Zareian *et al*. (2018a) gave a *b* value of 3.081 for 31 fish, 4.7-21.5 cm total length. Abbasi *et al*. (2019) gave a *b* value of 3.04 for 55 fish, 20.3-39.1 cm total length, from the Kardeh River. Growth was 1.5 times faster in lakes or reservoirs than in rivers (Gabrielian, 1998).

**Food.** This species is herbivorous and detritivorous and feeding occurs year-round but is less in late autumn, winter, early spring and during spawning (Gabrielian, 1998).

**Reproduction.** Females mostly matured at age $3^+$ years but could be $2^+$ or $4^+$ years old. Males matured at $2^+$ years. Spawning occurred from March to September over sand or rock at 5-50 cm depths with a slow current drift (Berg, 1948-1949; Gabrielian, 1998).

**Parasites and predators.** None reported from Iran.

**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern while noting droughts in the Hari River basin have destroyed many of its habitats. It was not thought to be declining fast enough to warrant another threat level.

**Sources.** Based in part on Zareian *et al*. (2018).

Iranian material:- CMNFI 1993-0138, 1, 129.5 mm standard length, Razavi Khorasan, Bazangan Lake (36º18'N, 60º27'E); CMNFI 2007-0014, 4, 39.4-99.1 mm standard length,

Razavi Khorasan, pool in Kuh-e Sang Park, Mashhad (ca. 36º18'N, ca. 59º36'E).

Comparative material:- BM(NH) 1886.9.21:170, 1, 64.4 mm standard length, Afghanistan, Kushk (= Koshk-e Kohneh, ca. 34°52'N, ca. 62°31'E); ZISP 10356, 13, 75.1-199.9 mm standard length, Turkmenistan, Tedzhen River (no other locality data); ZISP 13306, 5, 39.8-84.0 mm standard length, Afghanistan, Afghan-Iran border, Kyariz (possibly meaning a karez) on Hari River (no other locality data).

## *Capoeta kaput*

Levin, Prokofiev and Roubenyan, 2019

*Capoeta kaput*, 35.0 cm standard length, Armenia, Akhuryan River, Aras River tributary, Boris A. Levin.

*Capoeta kaput*, Turkey, Aras River, B-20 canal at Aralık (CC BY 4.0, after Kaya *et al*. (2020)).

**Common names.** Siyah mahi Aras, siyah mahi abi.

[Mavi Aras sirazı in Turkish (Kaya *et al*., 2020); blue scraper, blue Aras scraper].

**Systematics.** The holotype is under ZMMU (Zoological Museum of Lomonosov Moscow State University) P-23837, 26.2 cm standard length, Armenia (39°08′34″N, 46°50′21″E) and paratypes under ZMMU P-23838, 21.2 cm standard length, same locality ZMMU P23839, 22.0-25.8 cm standard length, same locality, and ZMMU P-23840, 21.3 cm standard length, Armenia (40°00′39″N, 44°23′28″E). The species is related to *Capoeta capoeta* but has unique nucleotide substitutions. The species name is from a local name based on the bluish colour of live fish, kaput meaning blue in Armenian. Note that the type locality may map out as in Azerbaijan because of differing political claims (B. A. Levin is thanked for this education on Caucasian politics).

**Key characters.** This species is distinguished from other large-scaled *Capoeta* species (60 or less lateral line scales) by having one pair of barbels, modally 9 dorsal fin branched rays,

an unusual bluish colour in live fish with body and fins darker than in related species, and a distribution in the Aras River basin of the Caspian Sea basin.

**Morphology.** The dorsal body contour is distinctly but smoothly arcuate with no marked discontinuity between the head and predorsal profile. The greatest body depth is at the level of the dorsal fin origin. The head is conical, with an almost straight dorsal profile, the snout is bluntly rounded and rounded in ventral view, and the interorbital space is convex. The head is deep (ca. 78% at nape) and wide (interorbital distance ca. 50% head length). The mouth is wide (ca. 40% head length), and weakly and variably arched. The lower jaw is covered by a sharp, horny sheath. The lips are adnate to the jaws, and smooth. The rostral cap is well-developed, partly overlapping the upper lip. Only the maxillary barbel is present. The dorsal fin origin is anterior to the pelvic fin origin, the dorsal fin outer margin is concave, and the first branched ray is the longest. The last unbranched dorsal ray is thick and ossified, massive at its base, serrated in the basal two-thirds, denticles straight and closely spaced (24-35 total), soft and flexible in the distal third. The pectoral fins extend back to before the vertical of the dorsal fin origin. The tips of the pelvic fins are remote from the anus. The anal fin outer margin is convex, the tip formed by the first and second branched rays. The caudal fin is deeply forked, the tips of its lobes being bluntly pointed. Further details on molecular, morphometric and osteological data and a comparison with *C. capoeta* are given in Levin *et al*. (2019).

Dorsal fin unbranched rays 4, branched rays 8-9, modally 9, anal fin unbranched rays 3, branched rays 5, pectoral fin branched rays 15-19, and pelvic fin branched rays 8. Lateral line scales 52-60, scales above lateral line 9-12 (or to 11.5), scales below lateral line (to pelvic fin) 7-9 (or to 8.5), and scales around caudal peduncle 20-23. Total gill rakers number 24-25. Pharyngeal teeth are 2,3,4-4,3,2 or 2,3,5-5,3,2 with thinner limbs connecting at a nearly straight angle (massive at a sharp angle in *C. capoeta*), and the shape of the masticatory plate is variable from almost triangular to pentagonal. Total vertebrae number 46-48.

**Sexual dimorphism.** Sexual dimorphism is apparently weakly-expressed apart from tuberculation. Large breeding tubercles on the snout are present in both sexes, being larger and more pronounced in males. During the spawning season tubercles appear on the last 2-3 anal fin branched rays.

**Colour.** In life, the body is silvery, darker at the back and on the dorsal and lateral sides of the head with differently expressed blue or blue-green colours. Scales are broadly margined by dark pigment forming a reticulate appearance. When preserved, overall colouration is brownish-yellow to olive-brown, head dorsally and laterally and the fins darker, the underside of the head and trunk lighter. Each scale is broadly margined by dark pigment. The cleithral stripe is narrow (up to a half-scale in width) or indistinct.

**Size.** Reaches 45.4 cm standard length.

**Distribution.** This species is found in the Aras River and its tributaries the Akhuryan and Mezamor rivers of Armenia (Levin *et al*., 2019). The Aras River at 39º08'34"N, 46º50'21"E, the type locality, is on the border with Iran and this species undoubtedly occurs in Iranian waters.

**Zoogeography.** A member of the Aralo-Caspian clade, see under the genus.

**Habitat.** Found principally in large rivers.

**Age and growth.** Unknown.

**Food.** Unknown.

**Reproduction.** Fish caught on 29 June bore tubercles indicating a spring to early summer spawning season.

**Parasites and predators.** Unknown.

**Economic importance.** Unknown.

**Experimental studies.** None.

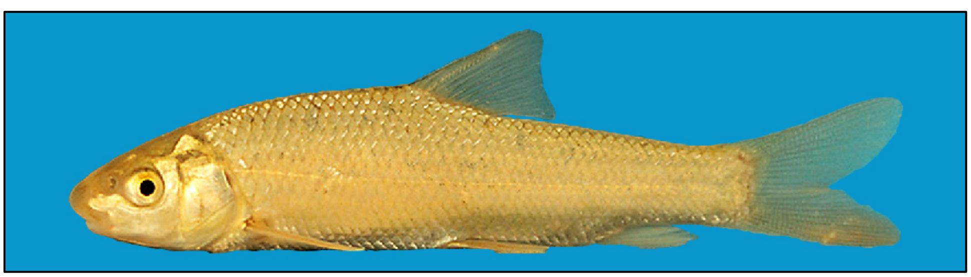
**Conservation.** Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern as a widespread species with no known major widespread threats.

**Sources.** Based on Levin *et al*. (2019).

***Capoeta macrolepis***
(Heckel, 1847)

*Capoeta macrolepis*, Hamadan, Haramabad, Gamasiab River, January 2010, Keyvan Abbasi.

*Capoeta macrolepis*, Fars, Denjan Spring, Kor River basin, Hamid Reza Esmaeili.



*Capoeta macrolepis*, Fars, Beshar River at Tang-e Tizab, Hamid Reza Esmaeili.

**Common names.** None.

[Kor scraper].

**Systematics.** *Scaphiodon macrolepis* was described from the "Confluenten des Araxes bei Persepolis" (presumably where the Pulvar (= Sivan) River enters the Kor River, Fars near Persepolis). Two syntypes of *Scaphiodon macrolepis* are in the Naturhistorisches Museum Wien under NMW 55896 and measure 100-175 mm standard length (Kähsbauer, 1964). Two other fish are marked as syntypes under NMW 51653 and are from Persepolis collected by Th. Kotschy. The catalogue in Vienna listed four fish and the 1997 card index agrees these four fish are the syntypes. Gandomkar *et al*. (2020) investigated genetic variation using DNA microsatellite loci among fish identified as *Capoeta aculeata* from three rivers, the Beshar, Khersan and Marun of the Iranian Tigris River basin. The average number of alleles per locus ranged from 4 to 14, while the average observed heterozygosity at various loci varied between 0.212 to 0.579, implying a moderate level of genetic variation. The Marun River population displayed the highest level of variability in terms of heterozygosity. Populations from the Marun River were highly distinct from populations of the Beshar and Khersan rivers. Gandomkar *et al*. (2021) also examined fish from these rivers and characterised and developed 36 novel polymorphic microsatellite markers. The average number of alleles per locus varied from 1.7 to 16.0 (average = 7.89). The polymorphism information content of these loci varied from 0.254 to 0.888. The observed heterozygosity per locus ranged from 0.17 to 0.881, while the expected heterozygosity per locus was from 0.17 to 0.881. Among these loci, 20 loci deviated significantly from the Hardy-Weinberg equilibrium. These microsatellite markers could provide a valuable tool for future population and conservation genetics studies.


*Scaphiodon macrolepis*, syntypes, NMW 55896, Naturhistorisches Museum, Wien.


*Scaphiodon macrolepis*, syntypes, NMW 55896, Naturhistorisches Museum, Wien.

**Key characters.** This species is distinguished from other large-scaled *Capoeta* species (60 or less lateral line scales) by having one pair of barbels, modally 8 dorsal fin branched rays, no sporadic pigmentation on the lower operculum, and a distribution in the Kerman-Na'in, Kor River, Persis and Tigris River basins. Characters are similar to and overlapping with those of *C. aculeata* (*q.v.*). There are three fixed, diagnostic nucleotide substitutions in the mtDNA cytochrome *b* and one in COI (Zareian *et al*., 2018).

**Morphology.** The body is rounded and is deepest just in front of, or at, the dorsal fin**.** The predorsal profile is gently convex and, in some fish, straight before the dorsal fin before sloping to the head. The caudal peduncle is compressed and relatively deep. The snout is rounded and the eye lies in the anterior half of the head. The rostral fold obscures the upper lip in the centre in larger fish and there is a groove across the snout in some fish. The mouth is u-shaped in young and a shallow arch with a very sharp, horny lower jaw in larger fish. The upper lip is moderately thick. The posterior barbel is thin and extends back to the anterior eye margin or to the pupil. The dorsal fin margin is weakly emarginate. The dorsal fin spine is moderate with medium-sized denticles on half of the spine or almost to a thin tip. The dorsal fin origin is anterior to the level of the pelvic fin origin. The caudal fin is moderately forked with tips rounded to slightly pointed. The anal fin margin is rounded and the fin does not reach back to the caudal fin base when appressed. The pectoral and pelvic fins are usually rounded and remote from the pelvic fin base and anal fin base respectively. The pectoral fin may have a straight margin.

Dorsal fin with 3-5 unbranched (modally 4) and 7-9 branched rays (modally 8), anal fin with three unbranched and 5-6 branched rays (modally 5), pectoral fin with 16-21 branched rays, and pelvic fin with 7-10 branched rays. Lateral line scales 37-51, predorsal scale rows 13-21, scale rows between the dorsal fin origin and the lateral line 6-9 (modally 8), scale rows between the anal fin origin and the lateral line 5-8 (modally 6), scale rows between pelvic fin origin and lateral line 5-8 (modally 6), and scale rows around caudal peduncle 15-21. The pelvic axillary scales are elongate. Scales have dorsal and ventral parallel to slightly rounded margins, a rounded posterior margin, and an anterior margin with indentations on each side of rounded central projection. The anterior scale margin may be irregularly indented. There are many fine circuli. The radii are few on the posterior field with none or few on the anterior field. The focus is subcentral anterior. Total gill rakers number 16-25. Pharyngeal teeth are scalloped and resemble those in *C. aculeata*. Teeth are 4 or 5 in the main row with 3 in the middle row and 2 in the outer row. Total vertebrae number 39-44.

Meristic values for Iranian specimens are:- dorsal fin branched rays 7(2), 8(134) or 9(2), anal fin branched rays 5(137) or 6(1), pectoral fin branched rays 16(5), 17(13), 18(43), 19(48), 20(24) or 21(5), pelvic fin branched rays 7(1), 8(59), 9(74) or 10(4), lateral line scales 37(1), 38(-), 39(5), 40(11), 41(19), 42(27), 43(16), 44(21), 45(14), 46(10), 47(7), 48(4), 49(-), 50(2) or 51(1), predorsal scale rows 13(1), 14(3), 15(41), 16(44), 17(32), 18(10), 19(5), 20(1) or 21(1), scales around the caudal peduncle 15(2), 16(9), 17(29), 18(29), 19(33), 20(13) or 21(3), total gill rakers 16(1), 17(6), 18(23), 19(23), 20(27), 21(16), 22(25), 23(12), 24(3) or 25(2), and total vertebrae 41(15), 42(49), 43(57) or 44(16). The two syntypes, NMW 55896, both have 43 vertebrae.

**Sexual dimorphism.** CMNFI 2008-0255 (3 fish, 122.5-143.7 mm standard length, no date) have a tubercle patch from the eye forward between the nostril and upper lip with none on the snout tip. Other fish have medium-sized tubercles from eye to eye below the nostril level including on the snout. Fewer and smaller tubercles are present on the operculum. Flank scales have up to five small and scattered tubercles with 1-2 larger tubercles on flank scales over the pelvic fin back to the caudal peduncle. Small tubercles are present on the base of the upper unbranched caudal fin ray with occasional tubercles on other rays. The largest tubercles are on the anal fin branched rays, present distally and few in number. Other fish also show fine tubercles on the dorsal head surface and large tubercles on the anal fin rays.

**Colour.** The back is gray to blackish or green- brown, or golden olive-green in smaller individuals. The upper flank is darker than the lower and the belly and lower flank are yellow up to the lateral line. The centre of the belly is white. Some smaller individuals have small black spots on sides and fins. The flanks above and below the lateral line have some light and dark stripes. Some fish have a basal spot on scale rows at and just above the lateral line. The anterior base of scales on the back and flanks is heavily pigmented. Scales generally are outlined by pigment. The sides of the head are golden-brown or golden gray. Fins are often yellowish-brown or dirty green, although the dorsal and caudal fins are darker than the others. There is a yellowish spot on the bases of the pectoral and pelvic fins. The iris is golden to orange, the upper part of iris being darker than lower part. Preserved specimens have pigment on the rays and membranes of all fins but without any distinctive pattern. Pelvic fins are weakly pigmented. The peritoneum is black.

**Size.** Reaches 37.3 cm total length (Esmaeili *et al*., 2014) .

**Distribution.** This species is found in the Kerman-Na'in, Kor River, Persis and Tigris River basins, in earlier records under the name *C. aculeata*. In the Kerman-Na'in basin generally; in the Kor River basin from the Kor, Marghan, Pulvar, Sevah (= Seveh), Shadkam and Sivand rivers, the Kor or Dorudzan Dam, Band-e Amir Spring, Ghadamgah Spring-Stream system, Gomban Spring and Kaftar Lake; in the Persis basin from the Kheyrabad and Mond rivers; and in the Tigris River basin from the Abshalamzar, Abshar, Armand, Badavar, Bala, Bazoft, Beheshtabad, Beshar, Chikhab, Dez, Dinorab, Doveyrich, Eivashan (= Eushan), Gamasiab, Gizeh, Hadi, Haramabad, Harud, Jarrahi, Joorab-Joozan, Kaaj, Kangavar Kohneh, Karkheh, Karun, Kashkan, Khersan, Khorram (Khorramabad), Malayer, Marun, Marvil-Bighash, Mehrgerd, Pol-e Doab, Qareh Su, Qodarkabk, Razavar (= Raz Avar), Simareh, Sulgan, Tang-e Sorkh and Tang-e Tizab rivers, Sangan Stream, the Agh-Gol, Choghakor (= Chagha Khur), Gamasiab, Haramabad, Khondab and Pirsalman wetlands, sarabs near Kermanshah, Vahdat (= Qeshlaq) Dam and the Mir Soleiman Spring (Rainboth, 1981; Bianco and Banarescu, 1982; Abdoli, 2000; Ghorbani Chafi, 2000; Fadaei Fard *et al*., 2001; Barzegar and Jalali, 2002; Barzegar and Jalali Jafari, 2006; Jazebi Zadeh and Shirin Abadi, 2008; Abbasi

*et al*., 2009; Alwan, 2010; Raissy *et al*., 2010, 2010, 2013; Teimori *et al*., 2010; Ansari and Raissy, 2011; Biokani *et al*., 2011; Maaboodi *et al*., 2011; Levin *et al*., 2012; Esmaeili *et al*., 2013, 2015; Rahimi and Tabiee, 2013; Pirali-khierabadi *et al*., 2014; Tabiee *et al*., 2014; Mohamadiyani and Keivany, 2015; Alwan *et al*., 2016; Ghanavi *et al*., 2016; Jouladeh-Roudbar *et al*., 2016, 2017; Radkhah and Nowferesti, 2016b; Taghiyan *et al*., 2016; Pirali Khirabadi *et al*., 2017; Zamanpoore and Yaripour, 2017; Darvishi *et al*., 2018; Ebrahimi Dorche *et al*., 2018; Esmaeili *et al*., 2018; Nasri and Eagderi, 2018; Zareian *et al*., 2018; Fatemi *et al*., 2019; Nasri, 2021).

**Zoogeography.** Zareian *et al*. (2018) placed this species in the Aralo-Caspian group of *Capoeta*, where it separated from *C. razii* (with *C. gracilis*) 1.78 MYA, with *gracilis* and *macrolepis* separating 1.16 MYA.

**Habitat.** This species is found in rivers, streams, pools, lakes, dams, marshes, springs and qanats. Collection data included a temperature range of 14-31ºC, pH 6.0-7.0, conductivity 0.48-20.0 mS, river width 3.0-100.0 m, slow to fast current, depth 50-150 cm, clear, cloudy or muddy water, mud, gravel or pebble bottoms, emergent, filamentous and encrusting vegetation, and grassy and bushy shores.

Habitat of *Capoeta macrolepis*, Fars, Kor River upper reach, Hamid Reza Esmaeili.

**Age and growth.** Esmaeili *et al*. (2014) gave a *b* value for 143 fish from the Kor River, 8.69-37.3 cm total length, as 3.0. Asgardun *et al*. (2015) examined fish from the Gamasiab River and found negative allometric growth. Mohamadiyani and Keivany (2015) found length-weight relationships for 85 fish, 14.9-20.1 cm fork length, from the Gizeh River in Lorestan were $W = 0.0001L^{2.61}$ for males and $W = 0.00009L^{2.67}$ indicating negative allometric growth. Radkhah and Nowferesti (2016b) examined 50 fish, 5.0-17.6 cm total length, from the Gamasiab River and recorded a *b* value of 2.92, sexes combined, indicating negative allometric growth, and condition factors of 0.83 and 0.87 for males and females respectively. Zareian *et al*. (2018a, 2018b) gave a *b* value of 3.207 for 40 fish, 8.7-19.9 cm total length.

**Food.** Keivany and Mohamadiyani (2015) found Gizeh River, Lorestan fish had gastrosomatic indices of 5.41 for males and 7.9 for females in July, 8.68 for males and 8.63 for

females in August and 8.5 for males and 7.44 for females in September. Females had a slightly better condition overall at 8.0 than males at 7.52.

**Reproduction.** Reproduction has not been studied in this species. Specimens examined by me from the Khorramabad River contained eggs 1.5 mm in diameter on 6 July 1977 (CMNFI 1979-0279) and some seemed to be reabsorbing eggs. Spawning presumably takes place in late spring and summer.

**Parasites and predators.** The original records referred to *C. aculeata* as host but have been re-assigned based on distribution to the current species. Barzegar and Jalali (2002) reported parasites from Kaftar Lake fish as *Lernaea cyprinacea* and *Trichodina* sp. Barzegar *et al*. (2004) examined fish from the Beheshtabad River in Chahar Mahall and Bakhtiari Province and found *Dactylogyrus lenkorani*, *Gyrodactylus* sp. and *Myxobolus* sp. Barzegar *et al*. (2008) recorded the digenean eye parasites *Diplostomum spathaceum* and *Tylodelphys clavata* from this fish in the Choghakhor (= Chagha Khur) Lagoon, Chahar Mahall and Bakhtiari Province. Raissy *et al*. (2010) found ichthyophthiriasis (infection with *Ichthyophthirius multifilis* - ich or white spot disease), which cause epizootics in wild and cultured fishes, in fish from the Armand River in Chahar Mahall and Bakhtiari Province. Raissy *et al*. (2009, 2013) reported on a parasitic outbreak of *Lernaea cyprinacea* in the Choghakhor (= Chagha Khur) Lagoon. Raissy and Ansari (2012) also examined fish from the Armand River and found *Ichthyophthirius multifilis* (Ciliophora), *Myxobolus musayevi*, *Dactylogyrus lenkorani* and *Gyrodactylus* sp. (Monogenea), *Allocreadium isoporum* (Digenea), *Lamproglena compacta* (Crustacea) and *Rhabdocona denudata* (Nematoda). Raissy *et al*. (2013) recorded parasites from fish in the Kaaj River, an upper Karun River tributary, namely *Ichthyophthirius multifilis* (Ciliophora), *Myxobolus musayevi* (Myxozoa), *Dactylogyrus lenkorani* (Monogenea), *Allocreadium isoporum* (Digenea) and *Rhabdochona* sp. (Nematoda). Pirali-khierabadi *et al*. (2014) recorded the protozoan *Trichodina* sp. and Pirali-Khierabadi *et al*. (2015) identified the metazoans *Dactylogyrus lenkorani*, *Gyrodactylus elegans* and *Rhabdochona denudata* in fish from the Bazoft River, Chahar Mahall and Bakhtiari Province. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Pallisentis cholodkowskyi* from fish in the Choghakhor (= Chagha Khur) Lagoon. Sayyadzadeh *et al*. (2016) found the anchor worm *Lernaea cyprinacea* in fish from the Kor River basin, presumably from the introduced species *Carassius auratus* and/or *Cyprinus carpio*.

**Economic importance.** None.

**Experimental studies.** Ansari and Raissy (2011) found fish, identified as *C. aculeata*, from the Beheshtabad River had mean concentrations of 133.5, 152.3 and 54.4 μg/kg for copper, iron and zinc, attributable to fertilisers from agriculture, but levels were safe for human consumption. Nasri (2021) investigated phenotypic abnormalities in 1,982 fish of 13 species from eight sites above and below Khorramabad in the Khorram River. Only *Capoeta aculeata* (= *C. macrolepis*) showed abnormalities such as caudal deformity syndrome, semi-operculum, and unidentified tissue lesions and this species was proposed as a biological indicator for water pollution monitoring.

**Conservation.** This species is widely distributed and not under more than general threat, especially in the large and diverse Tigris River basin. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern (as *C. aculeata*).

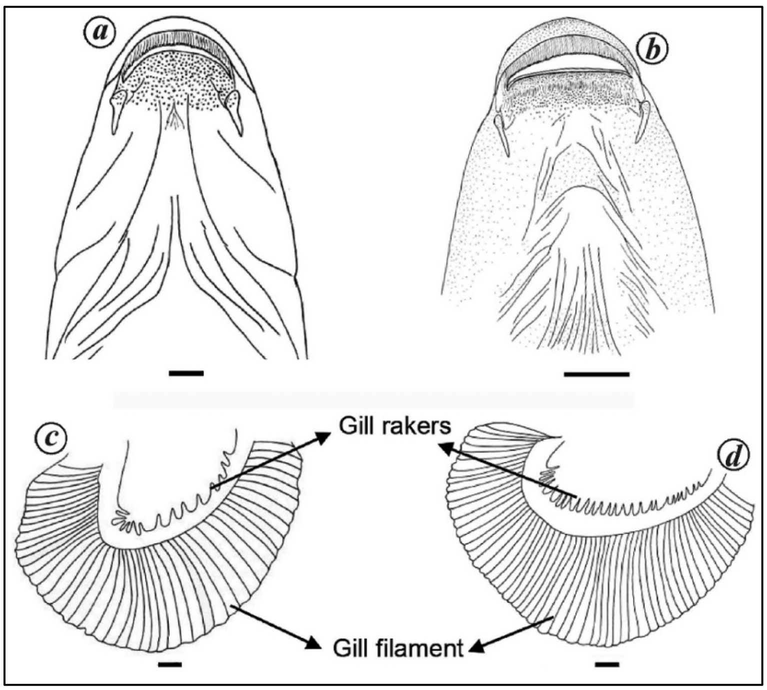
**Sources.** Zareian *et al*. (2018).

Iranian material:- CMNFI 1979-0025, 2, 65.3-68.1 mm standard length, Fars, Kor River at Marv Dasht (29º51'N, 52º46'30"E); CMNFI 1979-0059, 155, 22.9-67.4 mm standard length,

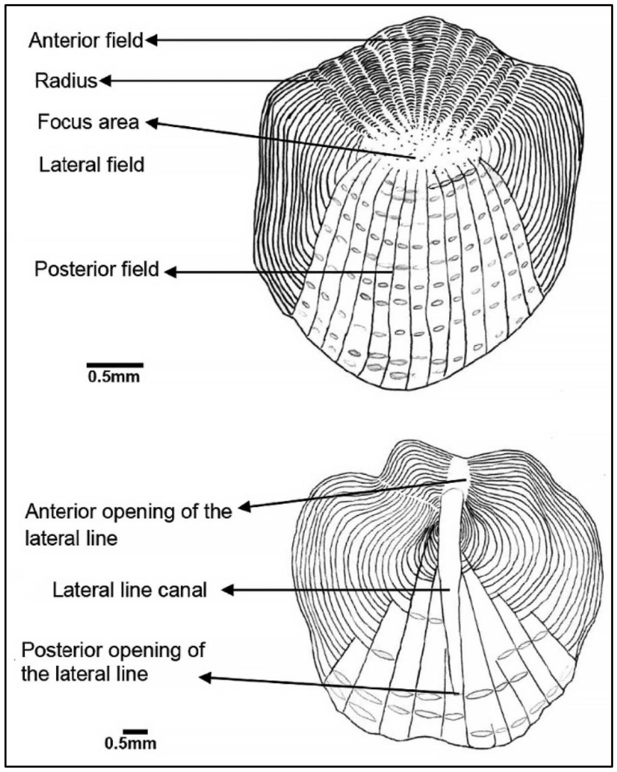
Fars, Pulvar River 8 km south of Sivand (30º01'30"N, 52º57'E); CMNFI 1979-0061, 8, 28.6-64.9 mm standard length, Fars, stream tributary to Pulvar River (30º04'N, 53º01'E); CMNFI 1979-0069, 1, 28.7 mm standard length, Fars, qanat at Naqsh-e Rostam (29º59'30"N, 52º54'E); CMNFI 1979-0070, 16, 25.9-60.0 mm standard length, Fars, Pulvar River near Naqsh-e Rostam (29º59'N, 52º54'E); CMNFI 1979-0116, 49, 24.3-52.1 mm standard length, Fars, Kor River near Marv Dasht (29º51'N, 52º46'30"E); CMNFI 1979-0117, 14, 34.4-44.1 mm standard length, Fars, Pulvar River at Naqsh-e Rostam (29º59'N, 52º54'E); CMNFI 1979-0270, 1, 121.8 mm standard length, Lorestan, Kashkan River drainage outside Khorramabad (33º26'N, 48º19'E); CMNFI 1979-0271, 1, 52.1 mm standard length, Lorestan, river in Kashkan River drainage (33º39'N, 48º32'30"E); CMNFI 1979-0273, 28, 51.4-104.5 mm standard length, Lorestan, Kashkan River drainage 5 km from Khorramabad (33º26'N, 48º19'E); CMNFI 1979-0274, 6, 20.6-59.2 mm standard length, Lorestan, river in Kashkan River drainage (33º27'N, 48º11'E); CMNFI 1979-0275, 1, 50.9 mm standard length, Lorestan, Kashkan River 2 km from Ma'mulan (33º25'N, 47º58'E); CMNFI 1979-0279, 18, 41.1-129.9 mm standard length, Lorestan, Khorramabad River (33º37'N, 48º18'E); CMNFI 1979-0282, 7, 99.2-130.8 mm standard length, Lorestan, river at Nurabad (34º05'N, 47º58'E); CMNFI 1979-0283, 2, 125.2-186.3 mm standard length, Kermanshah, river in Qareh Su drainage (34º21'N, 47º07'E); CMNFI 1979-0343, 1, 146.6 mm standard length, Fars, lake near Deh Bid (ca. 30º32'N, ca. 52º49'E); CMNFI 1979-0365, 1, 25.0 mm standard length, Khuzestan, stream in Doveyrich River drainage (32º25'N, 47º36'30"E); CMNFI 1979-0396, 9, 32.5-58.7 mm standard length, Khuzestan, Kheyrabad River 20 km from Behbehan (30º32'N, 50º23'30"E); CMNFI 1979-0460, 1, 77.6 mm standard length, Hamadan, stream 16 km south of Asadabad (34º38'N, 48º03'E); CMNFI 1979-0500, 2, 92.4-98.6 mm standard length, Fars, Pulvar River at Naqsh-e Rostam (29º59'N, 52º54'E); CMNFI 1993-0130, 2, 119.0-131.1 mm standard length, Kermanshah, sarabs near Kermanshah (no other locality data); CMNFI 2007-0116, 4, 77.4-95.4 mm standard length, Kermanshah, Gamasiab River basin west of Sahneh (ca. 34º28'N, ca. 47º36'E); CMNFI 2007-0117, 1, 138.6, mm standard length, Kermanshah, Gamasiab River basin near Sahneh (ca. 34º24'N, ca. 47º40'E); CMNFI 2007-0119, 1, 40.3 mm standard length, Kermanshah, Gamasiab River basin near Kangavar (ca. 34º31'N, ca. 48º03'E); CMNFI 2008-0184, 1, 91.9 mm standard length, Chahar Mahall and Bakhtiari, Armand River (31º37'N, 50º47'E); CMNFI 2008-0185, 2, 64.6-69.8 mm standard length, Chahar Mahall and Bakhtiari, Sulgan River (31º30'N, 50º50'E); CMNFI 2008-0235, 1, 154.1 mm standard length, Kermanshah, Razavar (= Raz Avar) River (34º25'N, 47º01'E); CMNFI 2008-0255, 3, 122.5-143.7 mm standard length, Fars, Kor River (30º00'N, 52º44'58"E); CMNFI 2008-0257, 1, 178.5 mm standard length, Fars, Marghan River near Sepidan (30º30'14"N, 51º53'19"E); ZSM 25703, 1, 76.3 mm standard length, Lorestan, Khorramabad River (no other locality data).

***Capoeta mandica***
Bianco and Banarescu, 1982

*Capoeta mandica*, Fars, Qarah Aqaj River near Kavar, Hamid Reza Esmaeili.




a and c, *Capoeta saadii*, 27.55 cm, b and d, *Capoeta mandica*, 30.15 cm (scale bar for a and b = 0.5 cm, for c and d = 0.1 cm), Azad Teimori.




*Capoeta mandica*, scale from between dorsal fin and lateral line above, and lateral line scale below, Azad Teimori.

**Common names.** Siah mahi-ye Dasht-e Arzhani or Arjani (Arzhan or Arjan Plain black fish), siyah mahi Mond.

**[**Mond scraper, Mond spotted barb].

**Systematics.** This taxon was described from the Mand (= Mond) River near Dasht-e Arjan, Fars as a subspecies of *Capoeta barroisi* Lortet in Barrois, 1894 which was described from the Orontes River basin in Syria. Note that Banarescu is spelled without accents in this paper with Bianco (and this is retained here and elsewhere).

*C. barroisi mandica* differs from the type subspecies (*C. barroisi barroisi*) and *C. b. persica* (see below) in number of scales (61-68 in *mandica* (58-68 in types examined by me), 69-82 in *barroisi*, 78-79 in *persica*), number of gill rakers (21-24 in *mandica* (22-27 in types examined by me and apparently number is related to size of fish), 27-31 in *barroisi*, 18 in *persica*), from *barroisi* in having usually 8 dorsal fin branched rays (*barroisi* has 9 but *persica* also has 8), and from *persica* by a straight mouth (also straight or transverse in *barroisi*, arched in *persica*). Krupp (1985c) considered the scale counts to be within the lower range of the nominal subspecies, gill raker counts and mouth position do not differ from the nominal subspecies, and the dorsal fin ray count of 8 is seen in the subspecies *mandica*. Krupp observed that meristic and morphometric characters are extremely variable in widely distributed *Capoeta* species and considered it to be a synonym of the nominal subspecies, *C. b. barroisi*. Ghanavi *et al*. (2016) found *C. mandica* was closely related to *C. trutta* and only distantly related to *C. barroisi*, using cytochrome *b* data. Özuluğ and Freyhof (2008) examined five juvenile specimens from the Mond River and considered the subspecies *mandica* to be a valid species.

Zareian *et al*. (2016, 2018) confirmed its distinction as a species in the *Capoeta trutta* group using total genomic DNA and mitochondrial COI and cytochrome *b* regions.

The holotype of *C. b. mandica*, 106.9 mm standard length, is in the Istituto di Zoologia dell'Universitá di L'Aquila, Italy (IZA 7890), with 95 paratypes from the same locality in IZA 7891 (now numbering 84 fish measuring 34.2-84.9 mm standard length) and five paratypes in the Institutul de Stiinte Biologice, Bucuresti, Romania (ISBB 3123), these 100 specimens having a standard length of 34-86 mm. Six paratypes of *mandica* (46.9-82.9 mm standard length) are in the Canadian Museum of Nature, Ottawa under CMNFI 1982-0366 (from IZA 7891, and listed under the old acronym as NMC 82-366 in the *Catalog of Fishes*, downloaded 30 May 2018).

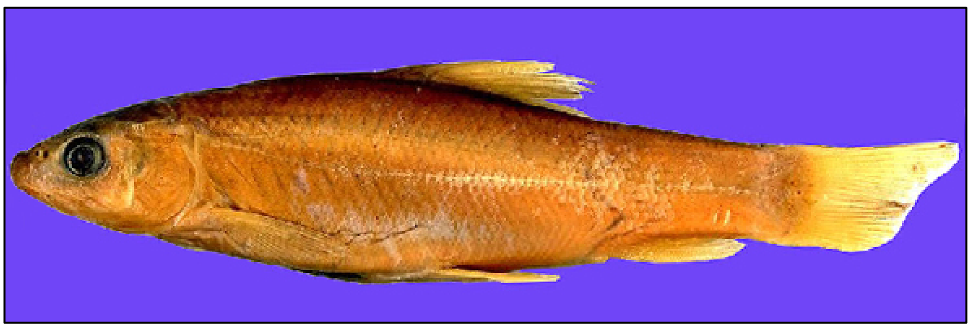

*Capoeta barroisi mandica*, paratype, CMNFI 1982-0366,
Bronwyn Jackson @ Canadian Museum of Nature.

Syntypes of *Capoeta barroisi* are in the Musée Guimet d'Histoire Naturelle, Lyon (MGHN 3492, 316 mm standard length, from the Orontes near Antakya in Turkey collected by E. Chantre and MGHN 3493, 278 mm standard length, from Buhairat Hims in Syria collected by Th. Barrois) (Krupp, 1985c).

*Capoeta barroisi persica* Karaman, 1969 was described from "See Zariwar, Mariwan, 120 km westlich v. Sannadaj" (Lake Zaribar near Marivan, Kordestan in the Tigris River basin). The subspecies *persica* was distinguished from the type subspecies by having a more horseshoe-shaped mouth, 8 dorsal fin branched rays, 18 gill rakers, blackish pectoral, pelvic and anal fins, few but very large black spots on the body, a shorter anal fin and a longer pectoral fin, and a deep body, based on a single specimen. Krupp (1985c) considered the characters of mouth form and colour to fall within the range of the nominal subspecies (and by implication the other characters too). Özuluğ and Freyhof (2008) found it difficult to reach a conclusion on the taxonomic status of this subspecies on the basis of a single specimen which could be abnormal. Zareian *et al*. (2016) regarded the subspecies *persica* as an aberrant *Capoeta trutta*.

*Capoeta capoeta intermedia* Bianco and Banarescu, 1982 (*non Capoeta intermedia* Temminck and Schlegel, 1846 = *Acheilognathus lanceolata* (Temminck and Schlegel, 1846) (see Boeseman, 1947)) described from the "Mand River near Akbar, southern Iran" is listed as synonym of *C. saadii* (Zareian *et al*., 2018; *Catalog of Fishes*, downloaded 17 July 2020). However, note counts of total gill rakers for this taxon (holotype and paratype IZA 7894, and three paratypes from CMNFI 1982-0367 (see below) are 24 or more, consistent with *C.*

*mandica* counts, and the fish have small upper flank spots. The holotype of *Capoeta capoeta intermedia* is in the Istituto di Zoologia dell'Universitá di L'Aquila, Italy (IZA 7892) and is 92.5 mm standard length, collected by P. Bianco and S. Zerunian, 27/5/1976. There are 62 paratypes (IZA 7893) from the same collection as the holotype measuring 36-87 mm standard length and 13 paratypes uncatalogued in the Institutul de Stiinte Biologice, Bucuresti, Romania (ISBB) measuring 68-86 mm standard length (Bianco and Banarescu, 1982). Another paratype under IZA 7894 measures 105.5 mm standard length was examined by me (the *Catalog of Fishes*, downloaded 30 May 2018 listed two fishes). A paratype of *Capoeta capoeta intermedia* from the Mond River in Fars is in the Zoologischen Instituts und Zoologischen Museums der Universität Hamburg (ZMH 6090, 83.2 mm standard length) (Wilkens and Dohse, 1993; examined by me), one paratype from the Mond is in the California Academy of Sciences, San Francisco (CAS 48113), one paratype from the Mond is in the United States National Museum, Washington (USNM 227935), and six paratypes are in the Canadian Museum of Nature, Ottawa under CMNFI 1982-0367 (formerly IZA 7893, listed in the *Catalog of Fishes*, downloaded 30 May 2018 under the old acronym NMC 82-367).



*Capoeta capoeta intermedia*, holotype, IZA 7892, Hamid Reza Esmaeili.


*Capoeta capoeta intermedia*, paratype, CMNFI 1982-0367, 73.3 mm standard length, Bronwyn Jackson @ Canadian Museum of Nature.

Arab and Keivany (2020) used geometric morphometric methods to compare samples from the Persis basin and found it possible to separate the Kheyrabad and Fahlian river populations.

**Key characters.** This species is distinguished from other *Capoeta* species by having 57-68 lateral line scales, 12-16 scales between the dorsal fin origin and the lateral line, the body and head with irregular brown to black speckles, and the dorsal fin spine is shorter than the head.

**Morphology.** The body is rounded and moderately deep although not as deep as that of *Capoeta trutta* but deeper than co-occurring *C. saadii*. Body depth is smaller than head length while it is deep and laterally compressed in *C. barroisi*. The body is deepest in front of the dorsal fin and the caudal peduncle is compressed and moderately deep. There is a predorsal ridge. The dorsal profile in front of the dorsal fin is convex and the snout is tapering and rounded. The snout has a groove in front of the nostrils. The rear of the eye is positioned at the beginning of the anterior half of the head. The mouth is subterminal and arched with a horny edge to the lower jaw. Even young fish have a gently arched mouth although it tends more to a u-shape. The upper lip is relatively thick and the lower lip is almost as thick at its corners as the upper lip. The thin barbel extends back to the anterior half of the eye. The dorsal fin margin is emarginate. The dorsal fin spine is moderately to strongly-developed although not as well-developed as in *Capoeta trutta*. Spine denticles extend almost to the thin and flexible tip. The dorsal fin origin is slightly anterior to the level of the pelvic fin origin. The depressed dorsal fin does not reach back as far as the anal fin origin level. The anal fin margin is straight or rounded and the fin does not extend back to the caudal fin base when depressed. The caudal fin is deeply forked with tips pointed to slightly rounded. The pelvic fin does not extend back as far as the anal fin origin and the pectoral fin does not extend back to the pelvic fin. Pectoral and pelvic fins are rounded versus pointed in *C. barroisi*.

Dorsal fin with 3-4 unbranched and 7-9 branched rays, usually 8 (usually 9 in *C. barroisi* according to Özuluğ and Freyhof (2008)), anal fin with 3 unbranched and 5-6, usually 5, branched rays, pectoral fin with 13-18 branched rays, and pelvic fin with 6-8 branched rays. Lateral line with 57-68 scales, and see below for other scale ranges. Belly scales are minimally to non-imbricate. There is a pelvic axillary scale. Scales have rounded dorsal and ventral margins leading to an extended and rounded posterior margin. The anterior margin is wavy or has a central rounded part flanked by weak indentations. There are relatively few anterior and posterior radii, often almost equal in number, the focus is sub-central anterior and circuli are fine. Teimori (2016) gave scanning electron microscopic details of scale structure as well as a macroscopic description. Total gill rakers number 21-30 reaching the second raker below when appressed. Pharyngeal teeth are in three rows, the main row with 4 or 5 scalloped teeth, the middle row with 3 teeth and the smallest row with 2 teeth. Total vertebrae number 41-45.

Counts from Alwan *et al*. (2016) are:- pectoral fin branched rays 13(1), 14(7), 15(2) or 16(1), pelvic fin branched rays 7(9) or 8(2), lateral line scales, 58(1), 59(-), 60(-), 61(1), 62(2), 63(1), 64(-), 65(2), 66(1), 67(2) or 68(1), scales around caudal peduncle 27(5), 28(1), 29(3), 30(1) 31(-), 32(-) or 33(1), and total gill rakers 23(2), 24(2), 25(2), 26(1) or 27(4). These match my counts below.

Meristic values are (including holotype and 4 paratypes):- dorsal fin branched rays 7(1) or 8(38), anal fin branched rays 5(38) or 6(1), pectoral fin branched rays 14(4), 15(16) or 16(18), pelvic fin branched rays 6(3) or 7(35), lateral line scales 57(1), 58(4), 59(2), 60(2), 61(2), 62(3), 63(3), 64(5), 65(4), 66(4), 67(-) or 68(2), scales above lateral line 12-16, scales below lateral line to anal fin 8-11, caudal peduncle scales 25-32, total gill rakers 22(4), 23(1), 24(4), 25(2), 26(8), 27(8), 28(2), 29(3) or 30(1).

**Sexual dimorphism.** Tubercles in males are found from eye to eye around the snout, starting just under the anterior eye and running below nostril level. In some larger individuals, fine tubercles are sparse on the top of the head and most flank scales have a single, centrally-placed tubercle as do scales on the lower caudal peduncle. There are some weak tubercles on the side of the head. There is a single row of tubercles on each of the last three anal fin rays. A

fish caught on 3 September 1978, 126.0 mm standard length (CMNFI 1979-0497) had weakly developed tubercles. The outer margin of the anal fin is straight in males, slightly convex in females. The anal fin is longer in females (4-8 scales between tip of anal fin and base of caudal fin in females, versus 7-10 in males).

**Colour.** Small black spots and speckles are present on the body above the lateral line but not the head (at least present on the dorsal head in *C. barroisi*). Spots are small, faint and usually indistinct below the lateral line or absent. Small individuals have more prominent and darker spots below the lateral line and lack the typical and identifying spotting pattern of adults. Spots are smaller than scale size. Rarely spots may be absent. The anterior scale base may bear a pigment blotch extending variably dorsally and ventrally. Overall body colour is silvery to a light brown or yellowish. The dorsal and caudal fins are greyish usually with a few scattered black spots. The pectoral fins are orange to yellow at the base, and the anal and pelvic fins are yellowish. All fins are speckled on rays and membranes although there are no clear rows of spots across the fins. Membranes can be darker than the fin rays in all fins although the pelvic fins can have darker rays. The pigmentation fades proximally on the pectoral and pelvic fins. The caudal fin bears many melanophores on both rays and membranes. Some fish have much lighter fins, perhaps the result of longer preservation. Pectoral, pelvic and anal fins are yellowish in life. The peritoneum is black.

**Size.** Attains 30.2 cm.

**Distribution.** This species is found in the Hormuz and Persis basins of Iran and was previously identified as *C. barroisi persica*. In the Hormuz basin from the Kul River; in the Persis basin from the Ahram, Dalaki, Daralmizan, Dasht-e Palang, Dehram, Fahlian, Helleh, Kheyrabad, Kohmareh Sorkhi, Mond, Qarah Aqaj, Rudbal (= Rudbar), Shur, Tang-e Sorkh and Zakheh rivers, Atashkadeh Stream and Lake Parishan **(**Alwan, 2010; Alwan *et al*., 2016, 2016; Teimori *et al*., 2010; Zareian *et al*., 2012, 2016; Golchin Manshadi *et al*., 2014, 2018; Pazira *et al*., 2014; Sadeghi Limanjoob *et al*., 2014; Esmaeili *et al*., 2015, 2017; Jouladeh-Roudbar *et al*., 2015; Mirdar Harijani *et al*., 2015; Ghanavi *et al*., 2016; Teimori, 2016; Gholamifard, 2017; Mohajeri Borazjani *et al*., 2017; Zamanpoore, 2017; Arab and Keivany, 2020).

Abdoli (2000) has the Jarrahi and lower Karun rivers, Biukani *et al*. (2013) the Gamasiab River, and Tabiee *et al*. (2014) the Beshar River in Kohgiluyeh and Bowyer Ahmad Province, all in in the Tigris River basin and requiring confirmation.

**Zoogeography.** *C. mandica* was originally described as a subspecies of a wide-ranging Southwest Asian species (*C. barroisi*), restricted to the Persis basin (Mond and Helleh river drainages). A relatively large area of suitable climate conditions for the species including the Kor River basin and southern parts of the Tigris River basin (not occupied by *C. mandica*) show a possible dispersal route of *Capoeta* from the Tigris River basin to the Persis basin, as previously assumed by Alwan *et al*. (2016b). Zareian *et al*. (2016) in confirming the validity of this species also confirmed the zoogeographical separation of the Persis basin by the post-Pleistocene rise in sea level, isolating rivers of the Tigris-Euphrates and western basins. Zareian *et al*. (2018) found *C. mandica* to be the most divergent species within the *C. trutta* species group, separating about 2.24 MYA.

**Habitat.** This species is found in rivers, streams, backwaters, lakes, dams and springs. Collection data included a temperature range of 9-30ºC (the lowest on 26 January 1976, CMNFI 1976-0020, the highest on 24 November 1976, CMNFI 1979-0129), pH 6.2-6.8, conductivity 0.55-4.9 mS, river width 1-30 m, still to medium current, depth 30-200 cm, clear or muddy water, mud, sand, gravel, pebble, stone or boulder bottoms, emergent rushes and

reeds, foliose or encrusting vegetation, and grassy, bushy or forested shores. The cyprinoids *Alburnus sellal*, *Capoeta saadii*, *Cyprinion tenuiradius*, *Garra mondica* and *G. rufa* coexist in different habitats (Zareian *et al*., 2018).

Zareian *et al*. (2016, 2018) mapped the potential distribution of this species using climatic data. Basins adjacent to the current distribution, such as the Kor River and southern Tigris River, were suitable. Habitat suitability was highest in areas in southwest Iran with more percent contribution of precipitation in the warmest quarter and mean temperature of the coldest quarter.

Habitat of *Capoeta mandica*, Fars, Rudbal River
(Rudkhaneh Rudbal …., in Farsi, RCC BY-SA 4.0, Ghasem4838).

**Age and growth.** Esmaeili *et al*. (2014) gave a *b* value for 355 fish from the Persian Gulf (Persis) basin, 5.59-21.3 cm total length, as 2.8. Fish from the Dalaki River (identified as *C. barroisi*) examined by Pazira *et al*. (2014) were mostly 100-150 mm in length and mostly age 3 years. The oldest fish was 6 years. Males had the highest obesity coefficient or condition factor (1.62-1.75 versus 1.55-1.62). The highest sex ratio was 1.65:1 for males at age 1 year at one locality. Total weights and lengths at three localities varied with age and with locality. The most annual survival was at age 2 and the most moment growth at age 2 (two localities) or 1 year (at one locality). Esmaeili *et al*. (2017) examined 335 fish, 5.6-21.3 cm total length, from the Rudbal (= Rudbar) River and found a male:female sex ratio of 2.5:1, males outnumbering females in all months, *b* values did not differ between males and females (range 2.1-3.13), and condition factor peaked in April for both sexes. Zareian *et al*. (2018a) gave a *b* value of 2.676 for 33 fish, 7.1-20.8 cm total length.

**Food.** Unknown.

**Reproduction.** Esmaeili *et al*. (2017) in their study found egg diameters up to 1.31 mm

with highest mean values in May, condition factors were highest in April, the female gonadosomatic index increased from March to May, peaking in the middle of spring, and decreasing significantly in June, leading to the conclusion that spawning occurred in May and June. The gonadosomatic index in males increased from December through April and then decreased in May and June. Details of maturation stages for both sexes were given.

**Parasites and predators.** Golchin Manshadi *et al*. (2017) recorded *Dactylogyrus pulcher* from fish identified as *Capoeta barriosi persica*, presumably the current species, from the Shapur River, Fars. Fish identified as *C. barroisi* from the Dalaki River were found to harbour *Rhabdocona* sp., *Contracaecum* sp. (Nematoda) and *Neoechinorhynchus zabensis* (Acanthocephala) (Mohajeri Borazjani *et al*., 2017). Golchin Manshadi *et al*. (2018) reported *Allocreadium* sp. from fish identified as *Capoeta barriosi persica*, presumably the current species, from the Fahlian River, Fars. Moumeni *et al*. (2020) recorded the zoonotics *Contracaecum* spp. from fish identified as *C. barroisi* in Iran.

**Economic importance.** This species has been caught on worm bait in the Dalaki River by A. Shiralipour (November 1976, CMNFI 1979-0125).

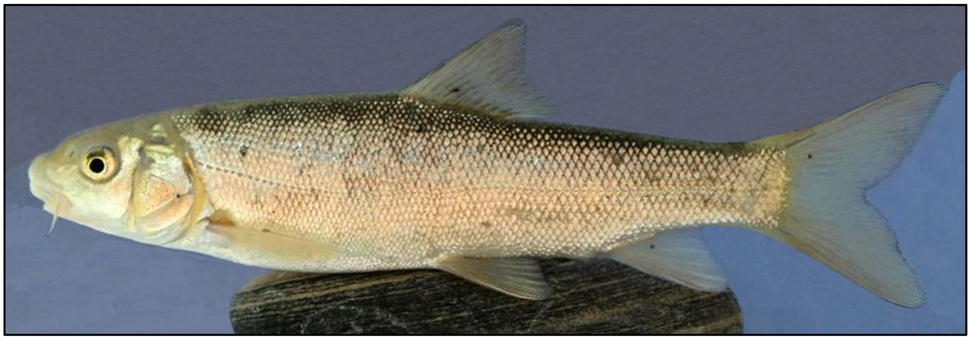
**Experimental studies.** None.

**Conservation.** Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern because it is widespread with no widespread threats.

**Sources.** Type material:- *Capoeta barroisi mandica* (IZA 7890, IZA 7891, CMNFI 1982-0366 (from IZA 7891) and ISSB 3123) and *Capoeta capoeta intermedia* (IZA 7892, IZA 7894, CMNFI 1982-0367 (formerly IZA 7893), ZMH 6090).

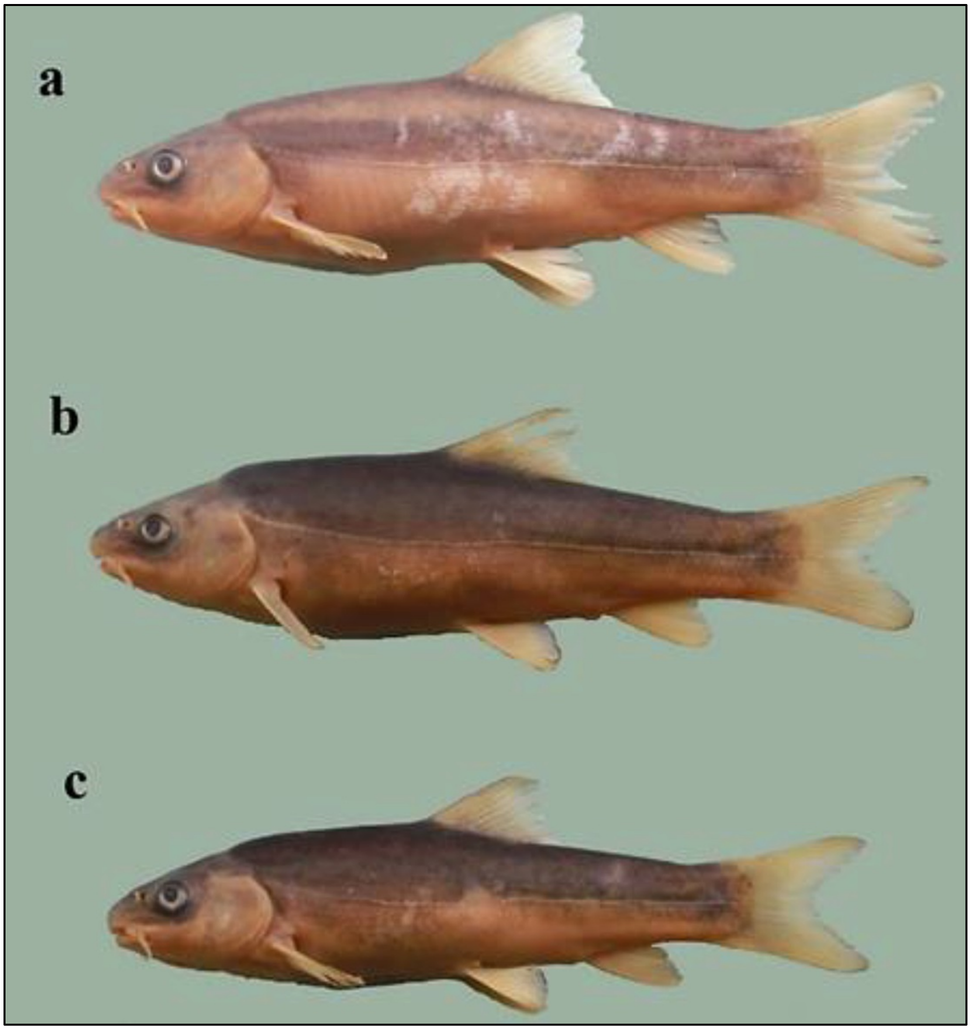
Iranian material:- CMNFI 1979-0020, 10 (in part), 33.4-80.3 mm standard length, Fars, Mond River outside Kavar (29º11'N, 52º41'E); CMNFI 1979-0053, 1, 76.0 mm standard length, Fars, Shur River tributary (ca. 28-29º58-03'N, ca. 52º34-35'E); CMNFI 1979-0075, 10 (in part), 40.0-201.2 mm standard length, Fars, Mond River at Pol-e Kavar (29º11'N, 52º41'E); CMNFI 1979-0079, 1, 159.7 mm standard length, Fars, Mond River 5 km above Band-e Bahman (ca. 29º12'N, ca. 52º38'E); CMNFI 1979-0080, 5, 58.5-247.2 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0109, 1, 91.1 mm standard length, Fars, Mond River at Shahr-e Khafr (28º56'N, 53º14'E); CMNFI 1979-0125, 1, 137.8 mm standard length, Bushehr, Dalaki River near Dalaki (ca. 29º28'N, ca. 51º21'E); CMNFI 1979-0128, 18, 17.2-135.3 mm standard length, Fars, Shur River between Atashkadeh and Firuzabad (28º51'N, 52º31'E); CMNFI 1979-0129, 1, 32.1 mm standard length, Fars, spring 2 km north of Farrashband (28º54'N, 52º04'E); CMNFI 1979-0154B, 6, 97.9-126.4 mm standard length, Fars, stream channels at Koorsiah (28º45'30"N, 52º24'E); CMNFI 1979-0198, 15, 30.4-45.6 mm standard length, Fars, stream at Tadovan (28º47'N, 53º24'30"E); CMNFI 1979-0202, 4, 21.5-25.1 mm standard length, Fars, Mond River (29º01'N, 53º00'E); CMNFI 1979-0497, 7, 102.2-132.0 mm standard length, Fars, Mond River at Band-e Bahman (29º11'N, 52º40'E); CMNFI 1993-0142, 1, 101.1 mm standard length, Bushehr, Dalaki River (no other locality data); CMNFI 2007-0063, 2, 76.4-77.6 mm standard length, Fars, Mond River tributary outside Jahrom (28º36'N, 53º37'E); CMNFI 2008-0254, 2, 178.5-184.3 mm standard length, Fars, Qarah Aqaj River (29º31'03"N, 52º15'E); CMNFI 2008-0259, 3, 106.1-140.7 mm standard length, Fars, Atashkadeh Stream near Fasa (28º56'18"N, 53º38'54"E); CMNFI 2008-0283, 1, 123.9, Fars, Rudbal (= Rudbar) River near Firuzabad (28º42’36”N, 52º38’12”E); ZMH 6086, 1, 73.6 mm standard length, Fars, Shur Fluβ, zufluβ von Mand-Fluβ.

***Capoeta pyragyi***
Jouladeh-Roudbar, Eagderi, Murillo-Ramos, Ghanavi and Doadrio, 2017



*Capoeta pyragyi*, ZM-CBSU Z760-767, Lorestan, Tireh River near Dorud,
Hamid Reza Esmaeili.

*Capoeta pyragyi*, 155.8 mm standard length, IMNRF-UT-1109 134, Lorestan, Tireh River,
after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.




*Capoeta pyragyi*, Lorestan, Sezar River near Dorud,
a) 72.0 mm standard length, ZM-CBSU Z750, b) 70.0 mm standard length,
ZM-CBSU Z751, c) 64.0 mm standard length, ZM-CBSU Z752, Hamid Reza Esmaeili.

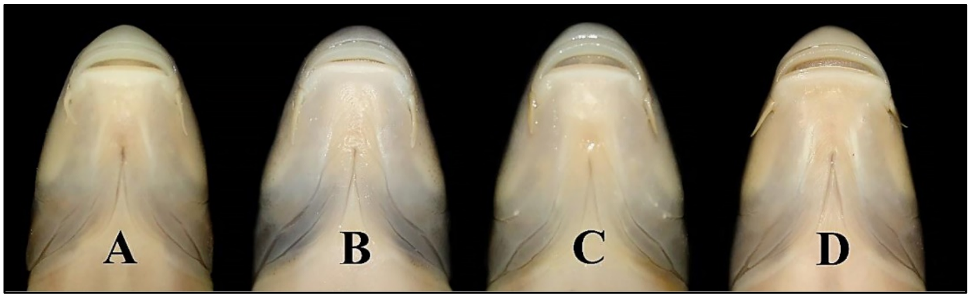
**Common names.** Siyah mahi Faraghi.

[Pyragy scraper, Sezar scraper].

**Systematics.** The holotype is under IMNRF-UT-1109 141 (Ichthyological Museum of Natural Resources Faculty, University of Tehran, Karaj), 118.1 mm standard length, Lorestan, Tire River at Kaghe Village, Sezar River drainage, Tigris River drainage, 33°37'06"N, 48°58'13"E and paratypes are under IMNRF-UT-1109, 16, 79.6-155.8 mm standard length, same locality as the holotype. The species is named to honor of Magtymguly Pyragy (a Turkmen spiritual leader and philosophical poet).

*Capoeta pyragyi*, holotype, IMNRF-UT-1109 141,
after Jouladeh-Roudbar *et al*. (2107), Soheil Eagderi.


*Capoeta pyragyi*, paratypes, A, 147 mm standard length, IMNRF-UT-1109 140,
B, 112 mm standard length, IMNRF-UT-1109 142, C, 109 mm standard length,
IMNRF-UT-1109 143, after Jouladeh-Roudbar *et al*. (2107), Soheil Eagderi.




*Capoeta pyragyi*, A, holotype, 118 mm standard length, IMNRF-UT-1109 141, paratypes, B, C, D (as B, C, A above), after Jouladeh-Roudbar *et al*. (2107), Soheil Eagderi.

**Key characters.** This species is distinguished from other small-scaled *Capoeta* species (61 or more lateral line scales) by having 12-16 scales between the dorsal fin origin and the lateral line, the body and head without irregular brown to black speckles, total gill rakers 15-19, dorsal fin branched rays modally 9, and a distribution in the Dez River basin of the Tigris River basin.

**Morphology.** The body is relatively high and compressed laterally. The dorsal profile of the head is slightly convex with a less arched ventral profile. The predorsal body profile is convex to straight with an elevated keel in front of dorsal fin origin. A nuchal hump may develop in some fish. The snout is rounded, blunt, and arched in ventral view. There is a groove across the snout anterior to the nostrils. The rostral cap is well-developed and partly covers the upper lip. Upper and lower lips are adnate to the jaws, and the lower jaw is covered with a keratinized edge. The mouth is sexually dimorphic being arched in males and straight in females. The maxillary barbel reaches back to the pupil. The dorsal fin origin is anterior to the level of the pelvic fin origin. The dorsal fin spine is moderately ossified, serrated and flexible distally, with 18-26 long denticles along 50-60% of the posterior margin, narrowly spaced and moderately strong. The dorsal fin margin is straight to concave. The depressed dorsal fin falls short of, or reaches, the anal fin origin level. The caudal fin is moderately forked with pointed to rounded tips, the ventral tip being rounder in some fish. The anal fin margin is straight to slightly rounded and the depressed fin does not reach back to the caudal fin base. The pelvic fin margin is slightly rounded to straight and fin does not extend back to the anal fin origin. The pelvic fin insertion is positioned posterior to the first branched dorsal fin ray. The pectoral fin has a slightly convex margin and does not extend back to the pelvic fin origin.

Dorsal fin with 4-5 unbranched and 8-9, modally 9, branched rays, anal fin with 3 unbranched and 5 branched rays, pectoral fin with 15-19 branched rays, and pelvic fin with 8-10 branched rays. Lateral line complete with 63-81 scales, 12-16 scales between dorsal fin origin and lateral line, 7-10 between anal fin origin and lateral line and 24-29 around the caudal peduncle. The pelvic axillary scale is well-developed, pointed, and triangular. Total gill rakers number 15-19, 13-15 on the lower limb, and are slightly hooked. The histology and histochemistry of the digestive tract was described as similar to other fishes by Asadi and Gharzi (2016) on fish identified as *Capoeta damascina* from the Sezar River but presumably the current species.

**Sexual dimorphism.** Unknown.

**Colour.** The back and dorsal head are brown, dark olive or golden, the flanks are light olive or pale brown with golden-yellow or golden-orange along the lateral line, and the belly is beige to white or cream. The operculum is light orange to golden-green. Dorsal, anal and caudal fins are dark yellow, cream, brown or grey with dark rays. The pectoral and pelvic fins

are golden-yellow. There are a few dark blotches or small black spots present on the body of some specimens. The peritoneum is black.

**Size.** Attains 33.8 cm total length (Alavi-Yeganeh *et al*., 2018).

**Distribution.** This species is found in the Dez River basin of the Tigris River basin in the Cheshmeh Langan, Sezar and Tireh rivers and possibly the Kurang River, Dez Dam and Gahar Lake (Jouladeh-Roudbar *et al*., 2017; Shirmohamadi *et al*., 2017; Zareian and Esmaeili, 2017; Alavi-Yeganeh *et al*., 2018). Sadeghinejade Masouleh (2008) identified *Capoeta damascina* specimens from the Bisheh-Dalan Wetland near Borujerd and these are probably the current species.

**Zoogeography.** See under the genus.

**Habitat.** This species is found in cold and slow flowing rivers and streams, with rock and stone bottoms, and gravel substrate, shaded by trees. Habitats can be quite dry or with flowing water as indicated below.

Type locality of *Capoeta pyragyi*, Lorestan, Tireh River at Kaghe Village,
after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

Habitat of *Capoeta pyragyi*, Lorestan, Tireh River near Dorud, Hamid Reza Esmaeili.

**Age and growth.** Alavi-Yeganeh *et al*. (2018) found a total length *b* value of 1.163 (and 0.927 for standard length) for 79 fish, 8.0-33.8 cm total length, from the Cheshmeh Langan River. Zareian *et al*. (2018a) gave a *b* value of 2.932 for 20 fish, 5.8-19.0 cm total length.

**Food.** Marammazi *et al*. (2014) examined fish from the Sezar River identified as *C*.

*damascina* but presumably *C. pyragyi* and found them to be herbivorous or periphyton feeders with a gastrosomatic index of 0.13, condition factor 1.41, index of fullness 340.96 and vacuity index 5.47. The diatom genera *Cymbella*, *Diatoma*, *Navicula* and *Nitzschia* were the main food items, with 14 supplementary genera and four incidental genera of diatoms and algae.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

**Economic importance.** The eggs of fish identified as *C. damascina* (possibly *C. pyragyi*) are reputedly poisonous and this is said to account for the low population of introduced *Oncorhynchus mykiss* (rainbow trout) in Gahar Lake, Lorestan (R. Mehrani, pers. comm., 2000).

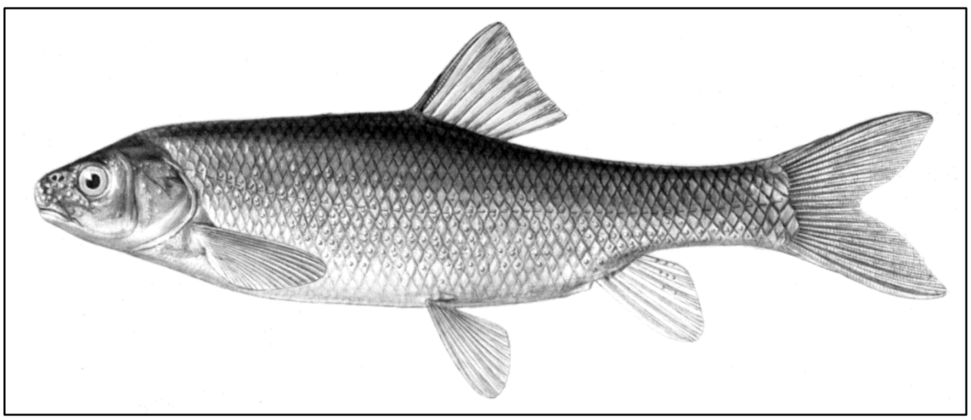
**Experimental studies.** Minabi *et al.* (2012) found that some body biochemical parameters (protein and fat but not ash or moisture) varied between summer and autumn, presumably related to food abundance, in fish from the Sezar River identified as *C. damascina* and presumably *C. pyragyi*.

**Conservation.** Jouladeh-Roudbar *et al.* (2020) listed it as of Least Concern because it is widespread and was not thought to have, or will, decline fast enough to qualify for another status. The Bisheh-Dalan Wetland habitat encompassing 913 ha is threatened with destruction (*Financial Tribune*, 4 August 2018).

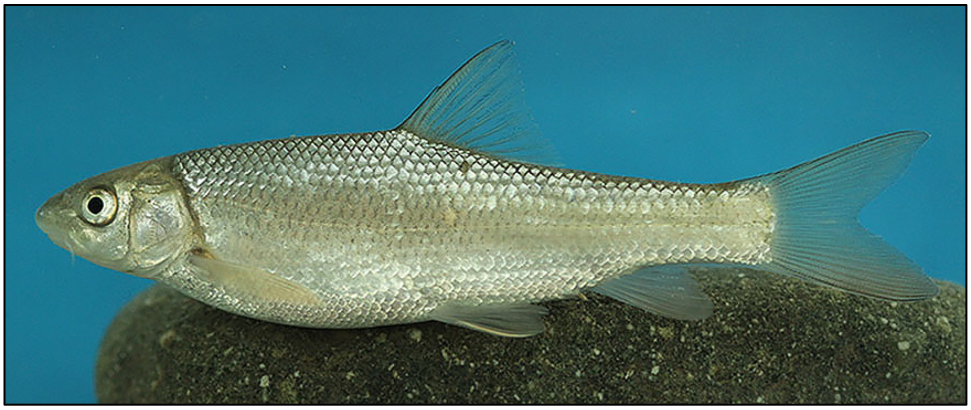
**Sources.** Based on Jouladeh-Roudbar *et al.* (2017).

### *Capoeta razii*

Jouladeh-Roudbar, Eagderi, Ghanavi and Doadrio, 2017

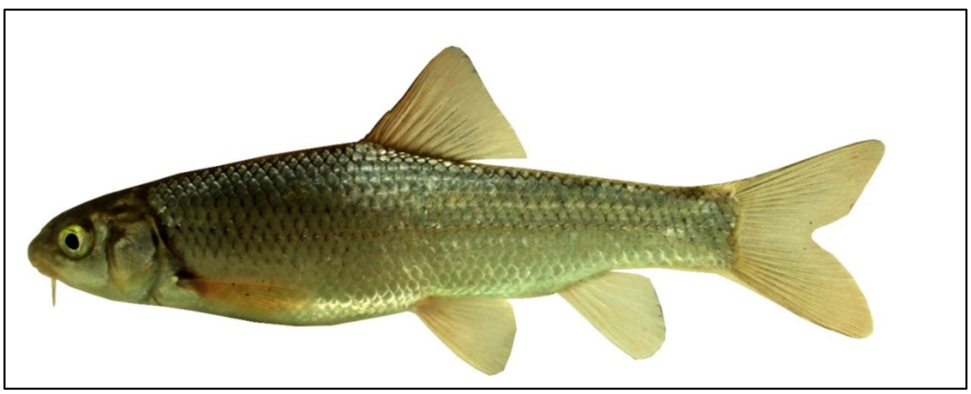


*Capoeta* razii (as *C. capoeta gracilis*), 14.0 cm total length, ZISP 14710, Azerbaijan, Bolgarchai River, Lenkoran District (Balharrud in its Iranian reach), after Berg (1948-1949).



*Capoeta razii*, Mazandaran, Tajan River, Hamid Reza Esmaeili.

*Capoeta razii*, North Khorasan, Bidvaz River, Dasht-e Kavir basin, Hamid Reza Esmaeili.



*Capoeta razii*, Iran, Arash Aarshaan.

*Capoeta razii*, 109.0 mm standard length,
ventral head, after Jouladeh-Roudbar *et al*. (2017).

**Common names.** Siyah mahi Caspian.

[Caspian scraper, blackfish (Ponnazar *et al*., 2018), Razi's scraper].

**Systematics.** The holotype is under IMNRF-UT-1072-9 (Ichthyological Museum of Natural Resources Faculty, University of Tehran, Karaj), 142.6 mm standard length, Mazandaran Province, Chalus City, Kheyroud River, Caspian Sea basin (36°36'35"N, 51°33'45"E) and paratypes are under IMNRF-UT-1072, 14 specimens, 90.7-184.2 mm standard length, locality same as holotype (and note figure below where other paratype numbers are cited but not in the text, presumably parts of IMNRF-UT-1072). The species is named in honour of Abū Bakr Muhammad ibn Zakariyyā al-Rāzī, a Persian polymath, physician, alchemist, and philosopher, for his important contributions in the history of medicine. He also discovered numerous compounds including ethanol (in which most fish collections are pickled).

*Capoeta razii*, holotype, after Jouladeh-Roudbar *et al*. (2017).


*Capoeta razii*, paratypes, after Jouladeh-Roudbar *et al*. (2017)
(A, IMNFR-UT-4, 130.0 mm standard length, B, IMNFR-UT-12,
115.0 mm standard length, C, IMNFR-UT-3, 99.0 mm standard length).

The *Capoeta* of the Caspian Sea basin of Iran were referred in the literature to *C. capoeta*, to *C. c. gracilis* or to *C. gracilis* even though *gracilis* was described from the Esfahan basin in central Iran (as *Scaphiodon gracilis*). The Iranian Caspian *Capoeta* are now placed in *C. razii*. *Capoeta capoeta* is restricted to the Kura and Aras River basins and the Lake Urmia basins. Fishes from Lake Sevan in Armenia, the Aras River basin in northwestern Iran (and neighbouring countries) and the Lake Urmia basin were referred to *C. sevangi* De Filippi, 1865 (e.g., see Esmaeili *et al*. (2018) and Zareian *et al.* (2018)) but are now recognised as *C. capoeta* (Jouladeh-Roudbar *et al*., 2020).

The following studies identified the fish variously as *Capoeta capoeta*, *C. c. gracilis* or *C. gracilis* but are all presumably *C. razii* based on distribution. Samaee *et al*. (2006) showed differences in morphometry between fish, identified as *Capoeta capoeta gracilis*, from six rivers along the Iranian Caspian shore with an overall assignment of individuals to a group of 88.6%. The morphometric data were mirrored by molecular data. Differences in morphometry were attributed to environmental and habitat conditions (temperature, turbidity, food availability, and water depth and flow) but molecular data indicated a genetic basis, presumably through lack of gene flow between the river populations. Samaee *et al*. (2009) examined morphological variation with this species in the Shirud of the south Caspian Sea basin. There were no significant differences in meristic characters but morphometric characters

varied and could be used to distinguish five groups. AnvariFar *et al*. (2010, 2011, 2012, 2013, 2013) compared fish, identified as *Capoeta capoeta gracilis*, from above and below the Shahid Rajaei Dam (built in 1995 on the Tajan River) and found the two populations to be morphologically and genetically different, indicating the elimination of upstream migration, limited downstream migration, and creation of two distinct populations. Heidari *et al*. (2013, 2014) compared fish, identified as *Capoeta capoeta* and *Capoeta gracilis* (but the same species), separated by the Manjil and Tarik dams on the Sefid River. Significant differences were seen in the snout, caudal peduncle and head, attributed to isolation of the populations and new environmental conditions. Heidari *et al*. (2013) and Zamani Faradonbe *et al*. (2015) investigated meristic and morphometric variation in this species, identified as *C. capoeta* and *C. gracilis* respectively, in the Sefid River basin, the latter finding differences in the head and tail regions, and fins, correlated with environmental conditions, particularly flow and substrate type. Eagderi *et al*. (2014) also compared fish, identified as *C. gracilis*, morphometrically above and below the Tarik Dam, in contrast finding no differences. Nedaei *et al*. (2014) compared fish, identified as *C. capoeta*, from the Aras and Sefid rivers finding the latter, presumably *C. razii*, had a larger head and shorter caudal peduncle, attributed to habitat separation (although these are now recognised as distinct species). Heidari *et al*. (2014) used truss analysis to trace the effects of Sefid River dams (Manjil and Tarik) on populations identified as *C. gracilis*. Analyses indicated morphologically different populations above and below the dams, attributed to elimination of migration by the dams. Salehinia *et al*. (2016) examined fish, identified as *C. gracilis*, from above and below the Sangban Dam on the Taleghan (= Taleqan) River and found two morphologically distinct populations, differing characters being body depth, head length and depth, and caudal peduncle depth. Malvandi *et al*. (2020) employed cytochrome *b* gene sequence analysis on fish identified as *C. gracilis* from the Cheshmeh Kileh, Siah, Tajan and Zarrin Gol rivers and found that populations were probably in equilibrium and were not experiencing a population expansion, and that distinct populations live in these rivers.

**Key characters.** This species is distinguished from other large-scaled *Capoeta* species (60 or less lateral line scales) by having one pair of barbels, modally 8 dorsal fin branched rays, and a distribution in the Caspian Sea basin (except the Aras River basin which has *C. capoeta* and *C. kaput*). *C. razii* is also distinguished from all other species of the *C. capoeta* species group by having four fixed, diagnostic nucleotide substitutions in the mtDNA cytochrome *b* region (Zareian *et al*., 2018).

**Morphology.** The body is moderately deepened and compressed laterally. The greatest body depth occurs at the level of the dorsal fin origin, or slightly to well in front. The dorsal profile of the head is slightly convex. The predorsal length is equal to the post-dorsal length. The predorsal profile of the body is straight to slightly convex without any marked keel in the front of dorsal fin origin but is somewhat compressed. The caudal peduncle is compressed and moderately deep. The snout is rounded with a triangular profile in ventral view. The mouth is ventral and almost straight in adults, u-shaped in young. Juvenile fish of similar size from the same collection may have a u-shaped mouth with little or no horny edge development or a narrowly arched mouth with an evident dark horny edge, e.g., CMNFI 2007-0106 fish at ca. 90.0 mm and 78.0 mm standard length. Larger fish have a depression across the snout in front of the nostrils. The upper and lower lips are adnate to jaws and the upper lip is relatively thick. The lower jaw has a strong keratinized edge in adults. The rostral cap is well-developed and usually overlaps the upper lip but not fully covering it. There is one set of maxillary barbels

that are short, moderately thick, tapering a little and slightly smaller than the horizontal diameter of the eye, reaching back to the anterior part of the eye or to the posterior margin of the orbit. Rarely barbels are absent, e.g., CMNFI 1979-0486, 60.1 mm standard length. Some fish rarely have additional barbels, e.g., in CMNFI 1970-0517 one fish has an anterior left barbel, in CMNFI 1979-0589 one fish has an anterior right barbel, and in CMNFI 1979-0434 the fish has two pairs of well-developed barbels. The intranasal length is slightly shorter than snout length. The eye is in the anterior half of the head. The dorsal fin outer margin is straight or slightly concave. The dorsal fin origin is anterior to the level of the pelvic fin origin. The last unbranched dorsal fin ray is thickened and serrated, distally flexible, and with 15-25 denticles on its posterior margin, with serrations along 50-70% of its posterior margin, denticles are long and narrowly spaced but relatively well-developed. Young fish have a greater denticle extent.

Last dorsal fin unbranched ray, above *C. capoeta* (IMNRF-UT-1067-13, 121.0 mm standard length); below *C. razii* (IMNRF-UT-1066-9, 116.0 mm standard length), after Jouladeh-Roudbar *et al*. (2017).

The last unbranched dorsal fin ray is slightly shorter than the first branched ray. The dorsal fin when appressed does not reach back to the level of the anal fin origin. The caudal fin is moderately to deeply forked with pointed to rounded lobes which are equal sized or the lower lobe is slightly larger. The anal fin margin is usually convex or straight and the fin does not reach back to the caudal fin base, or almost to the base in a female with eggs, for example. The pelvic fins have a rounded margin and lie under the level of the anterior branched dorsal fin base. The pelvic fins do not reach back to the anal fin origin but are closer in young fish. The pectoral fins are rounded and do not reach back to the pelvic fins.

Dorsal fin unbranched rays 3-5, modally 4, dorsal fin branched rays 7-10, modally 8, anal fin unbranched rays 2-4, modally 3, anal fin branched rays 5, pectoral fin branched rays 16-21, and pelvic fin branched rays 7-10, mostly 8-9. Lateral line scales 39-59 (usually 49-57), scales above the lateral line 7-11, scales below the lateral line 5-10, and scales around the caudal peduncle 17-26. Scales are regularly arranged over the body. The lateral line is complete. The pelvic axillary scale is triangular, well-developed, and pointed. There are numerous small scales on the caudal fin base extending distally on the fin membranes for more than half the fin ray length. Scales have a wavy anterior edge, few anterior and posterior radii, an almost central focus and many fine circuli. Scales have dorsal and ventral margins straight to gently convex, the posterior margin is rounded, and the anterior margin is indented on each side of the rounded centre and has abrupt rounded dorsal and ventral corners. Anterior radii are few while posterior radii are few to moderate in number. Posterior radii can be as few as five

and anterior as few as two. Total gill rakers number 15-26, mostly 17-22. Pharyngeal teeth are 2,3,5-5,3,2 with sometimes only 4 major row teeth. Teeth are scalloped with the largest tooth (number 4) more rounded. Total vertebrae number 41-47. Fish identified as *C. capoeta*, but presumably *C. razii*, from the Sefid River, the Shah in Rudbar and the Madarso (= Madar Su) River in Golestan National Park have 2n = 150, NF = 230-234 (Pourali *et al*., 2000; Pourali Darestani *et al*., 2006).

Meristics for Iranian specimens are:- dorsal fin branched rays 7(11), 8(131), 9(12) or 10(1), anal fin branched rays 5(155), pectoral fin branched rays 16(1), 17(47), 18(55), 19(38), 20(12) or 21(2), pelvic fin branched rays 7(1), 8(92), 9(59) or 10(3), lateral line scales 47(3), 48(3), 49(10), 50(23), 51(27), 52(22), 53(22), 54(18), 55(9), 56(8), 57(7), 58(2) or 59(1), total gill rakers 16(1), 17(8), 18(15), 19(41), 20(43), 21(26), 22(15), 23(3), 24(2), 25(-) or 26(1), and total vertebrae wide-ranging 41(5), 42(39), 43(47), 44(41), 45(16), 46(4) or 47(2).

**Sexual dimorphism.** Aburakhmanov (1962) examined fish, identified as *C. capoeta gracilis* (= *C. razii*), from the Lenkoran which is near the western Iranian border, and found a suite of morphometric differences between males and females (* = larger in males) including head (eye diameter*, interorbital distance, snout length), body (head depth, body depth, predorsal length, post dorsal length*, caudal peduncle length*) and fin (anal fin height, pelvic to anal fin length, lower caudal lobe length*) characters.

Males bear tubercles from under the eye and around the snout below the nostril level, the largest tubercles being on the snout. Large tubercles are present on anal rays 1 to 5, sometimes only on rays 3 to 5, but are few in number, and are mostly distal, or along the whole ray. Fine tubercles may be present on top of the head, the operculum, and numbering 1-4 on back scales. Lower flank scales from the pelvic fin level to the caudal fin have 1-2 small tubercles on each scale. The above was based on fish caught on 7 June 1978 (81.1-97.3 mm standard length, CMNFI 1979-0451), 8 June 1978 (102.5 mm standard length, CMNFI 1979-0453) and 7 July 1978 (115.8 mm standard length, CMNFI 1979-0491).

**Colour.** The upper part of the body is golden-brown, brownish, light olive, olive-green to green, yellowish or silvery, the flanks are light silver, silvery or silvery-gray, or yellowish, the belly is whitish, pearly white or dirty yellow up to the lateral line level. The head is dark-brown or dark-olive to olive-green on top and the sides are pale brown to white. There is a dark olive stripe extending along the lateral line in some fish. The iris is silvery or golden in the outer margin. Scales may be clearly outlined by pigment on the upper flank. The anal, pectoral and pelvic fins are hyaline or light brown, and the dorsal and caudal fins have a narrow black line. The front of the dorsal fin and margin of the caudal fin are black while the remainder of these fins is olive or yellowish. The black margin to the caudal fin may be best-developed on the upper and lower lobes as compared to the posterior margin. There are no lines of spots on the fins. Minute black spots are present on the flanks of fish smaller than 50.0 mm standard length. Preserved fish are dark brown on the back and flanks and yellowish-white on the belly. The head dorsally is dark brown and the sides beige. Fins are often light brown and the pelvic and anal fins may be yellowish or hyaline. The dorsal and caudal fins are darker than lower fins. The peritoneum is dark.

**Size.** Attains 184.2 mm standard length, 19.9 cm total length (Kor *et al*., 2017), to 23.5 cm total length (Ghasemzadeh-Sarcheshmeh *et al*., 2018; Mousavi-Sabet *et al*., 2018a), or to 35.0 cm (Berg, 1948-1949).

**Distribution.** This species is found in the Caspian Sea and Dasht-e Kavir basins of Iran. In the Caspian Sea basin from the Astara to the Atrak rivers, including upper reaches of

the Qezel Owzan and recorded from the Aghala, Alamut, Angueta, Aria, Asalem, Astara, Atrak, Baba Aman, Babol, Balhar, Beghbaghi, Chalk, Chalus, Chavrud, Chelchai (presumably Qal'eh), Chelond, Chelvand, Cheshmeh, Cheshmeh Kileh, Chubar, Dogh, Garkan, Garm, Gholab Ghir, Gohar, Golestan, Gonbad, Gorgan, Haraz, Harisek, Havigh (= Haviq), Kaboodval, Kalarud, Kargan, Karkan, Kazem, Kelar Abad, Keselian (= Kaslian), Khazar, Kheyr, Khushavar, Kiarud, Larim, Lavij, Lisar, Lomir, Madar Su, Mars, Masoleh, Masuleh-Rukhan, Molahadi, Nahang, Neka, Nesa, Pir Bazar, Pirsalman, Pishkamer, Polrud (= Pol-e Rud), Qareh Su, Qezel Owzan, Qotor, Ramian, Sagel, Sardab, Sefid, Shafa, Shah, Shahrbijar, Shalman, Shirabad, Shirud, Siah, Siah Darvishan, Tajan, Talar, Taleqan, Tilabad, Tonekabon, Tutkabon, Valam, Yasalegh, Zanjan, Zarem, Zarrin Gol and Zav rivers, and the Alborz, Golabar, Gorgan, Manjil or Sefid, Nazdik, Sangban, Shahid Rajaei, Tabarak, Taham, Taleqan, Tarik and Zire dams, the Fereydun Kenar International Wetland, and Gorgan Bay (Derzhavin, 1934; Bianco and Banarescu, 1982; Holčík and Oláh, 1992; Kiabi *et al*., 1994; Roshan Tabari, 1997; Shamsi *et al*., 1997; Karimpour, 1998; Abbasi *et al*., 1999, 2017; Kiabi *et al*., 1999; Abdoli, 2000; Nazari, 2002; Mostafavi and Abdoli, 2005; Abbasi *et al*., 2007, 2015; Aghili *et al*., 2008; Abdoli and Naderi, 2009; Gholizade *et al*., 2009; Kazemian *et al*., 2009; Piri *et al*., 2009; Shajiee *et al*., 2009; Mirzajani, 2010; Banagar *et al*., 2011; Ahmadpour *et al*., 2012; Mirzajani *et al*., 2012; Shamekhi Ranjbar *et al*., 2012a, 2012b; Yousefzade *et al*., 2012a, 2012b, 2014; Ghorbani *et al*., 2013; Abdoli *et al*., 2014; Aliakbarian *et al*., 2014; Gholizadeh *et al*., 2014; Heidari *et al*., 2014; Malvandi *et al*., 2014; Asadi *et al*., 2015; Jafarzadeh *et al*., 2015; Rahimibashar *et al*., 2016; Asadi *et al*., 2017; Babaei, 2017; Kor *et al*., 2017, 2018; Jouladeh-Roudbar *et al*., 2017; Naderi Jolodar *et al*., 2017; Rostamian *et al*., 2017; Taheri Mirghaed *et al*., 2017; Zamani Faradonbe *et al*., 2017; Ghasemzadeh-Sarcheshmeh *et al*., 2018; Mousavi-Sabet *et al*., 2018a; Rustami *et al*., 2018; Nasrolah Pourmoghadam *et al*., 2019; Shahnazari *et al*., 2020; Aazami and Alavi Yeganeh, 2021; Abbasi *et al*., 2021, 2021; Moradpour DerazKolaei *et al*., 2021); and in the Dasht-e Kavir basin from the North Kavir according to Zareian *et al*. (2018).

Jouladeh-Roudbar *et al*. (2020) reported translocations with commercial carps to the Namak Lake and Tigris River basins and corrected the erroneous type locality listed in Esmaeili *et al*. (2018).

**Zoogeography.** Zareian *et al*. (2018) placed this species in the Aralo-Caspian group of *Capoeta*, diverging from *C. gracilis* plus *C. macrolepis* 1.78 MYA.

**Habitat.** This species is found in rivers, streams, wetlands and dams, being one of the most abundant species in the Caspian Sea basin along with *Alburnoides* sp. (now several species), the most abundant fish in the Gorgan River for example (*Iranian Fisheries Research and Training Organization Newsletter*, 19:4, 1998; Soltanian *et al*., 2017).

The type locality had a medium to fast current, 3-14 m river width with a maximum depth of 1.0 m, cobble and gravel river bed, and the riparian vegetation was deciduous forest. The type locality also had *Alburnoides tabarestanensis*, *Alburnus chalcoides*, *Barbus cyri*, *Luciobarbus capito*, *Luciobarbus mursa*, *Squalius turcicus*, *Cobitis faridpaki* (Cobitidae) and *Ponticola iranicus* (Gobiidae).

Rezaei *et al*. (2007) recorded the frequency of this fish in the Madar Su Stream of Golestan Province from November 2003 to December 2004 after huge floods in 2001 and 2002. The mean catch per unit effort was 579 fish and absolute frequency was 2.33 fish per square metre, higher than before flooding and attributed to algal blooms. Fish frequency and flow speed were inversely related. It was found to be resistant to environmental changes, such

as flooding, in the Madarsoo (= Madar Su) River in Golestan (Rezaei *et al*., 2008). Zarei *et al*. (2014) sampled fish from 33 stations in the Taleghan (= Taleqan) River of the Sefid River basin, both above and below the Taleghan (= Taleqan) Dam. The temperature range was 8-18°C (15-18°C selected), depth was 10-55 cm (35-50 cm), river width was 250-22,500 cm (less than 1.0 m) and stone size was 6-60 cm (18-42 cm). Asadi *et al*. (2015) determined that fish in the Siah River (also a Sefid River tributary) showed a preference for a depth range of 17-38 cm, a water velocity of 0.44-0.56 m/s and a cobble substrate. Ghorbani *et al*. (2015) found that this species was dominant in the Tilabad Stream of Golestan and it was positively correlated with turbidity and stream width. Zamani Faradonbe *et al*. (2015, 2015) found a habitat suitability index of 0.813 (excellent) for this species in the Taleghan (= Taleqan) River with altitudes of 1,400-1,550 m, depth ranges of 40-55 cm, river width lower than 5 m, velocity 0.3-0.6 m/s, bottom stones 30-45 cm wide and temperature 16-18°C. Zamani Faradonbe and Eagderi (2015) found Taleghan (= Taleqan) River fish occupied all possible habitats due to their high adaptability to a great range of environmental factors. Abundance did not show any distinctive relationship with habitat variables in contrast to *Barbus cyri* (*q.v.*). Zarei *et al*. (2016) found that fish in the Taleghan (= Taleqan) River, longer than 11.0 cm total length, selected habitats with higher elevation, greater river width, higher water velocity, regions with larger bed stones and lower temperatures, in contrast with fish smaller than 11.0 cm.

Gholizadeh (2016) and Gholizadeh and Harsij (2016) found that Zarrin Gol Stream fish had a maximum abundance in forested habitats and a minimum in residential land habitats. A strong relationship was noted with flow variability and immediate land use while macroinvertebrates correlated most strongly with the dominant substrate. Riparian forest was important for maintaining habitat diversity and fish communities but fish communities were only correlated with the proportion of riparian farmland.

Rostamian *et al*. (2017) examined habitat use in the Kalarud, Mazandaran at eight stations finding high velocity, a rock bed, and greater width and depth were characteristic for this species. Abbaszadeh *et al*. (2019) compared fish of different ages in the Zarem Stream, a tributary of the Tajan River. The most preferable flow velocity for 0+ fish was 16-30 cm/s and for 1+, 2+ and 3+ fish 76-115 cm/s. The most preferable depth for 0+ fish was 16-60 cm, for 1+ and 2+ 16-90 cm and for 3+ 16-115 cm. All ages preferred macrolithal (blocks), mesolithal (cobbles) and microlithal (coarse gravel) substrates. Furthermore, 0+, 1+ and 2+ fish preferred argyllal (loam), but 3+ did not. Akal (fine gravel) was not preferable at all ages. Regarding biotic substrate preference, the results revealed that all ages mostly preferred fine roots and floating riparian vegetation although 1+ and 3+ fish also preferred coarse particulate organic matter and fine particulate organic matter to some extent. Fazel *et al*. (2019) found fish presence in the Tilabad and Zarrin Gol streams was highly correlated with in-stream vegetation and cobble on the first axis of a redundancy analysis and low flow mean depth and low flow width on the second axis.

Moradpour DerazKolaei *et al*. (2021) sampled fish identified as *Capoeta capoeta* from the Roodbabol branch of the Babol River in Mazandaran at 20 stations and 11 habitat factors were measured. Fish were found to prefer wide locations with low water flow, a temperature between 14 and 18°C, an average depth of 22-30 cm, an average altitude of 140-180 m, an average conductivity of 260-300 µS/cm, a small grain size for the substrate of 100-125 mm, a high level of dissolved oxygen at 12-13 mg/l, an average salinity of 1.5-1.7 mg/l, and coverage of bushes and shrubs with a shadow level of 41-70%. Abundance differences between stations

were affected by factors of depth and width in the first order and water flow and conductivity in the second order.

*Capoeta razii*, type locality, Mazandaran, Chalus City, Kheyroud River, after Jouladeh-Roudbar *et al*. (2017).

Habitat of *Capoeta razii*, CMNFI 1979-0492, Golestan, Tilabad River in Gorgan River drainage, 8 July 1978, Brian W. Coad.

**Age and growth.** In the Madarsoo (= Madar Su) Stream of Golestan National Park, this species had age groups 0-10 years and growth parameters were $L_t$ = 229.67 mm and K = 0.54 for males, 327.95 mm and 0.18 for females (Kouhestan Eskandari, 2003). Rezaei *et al*. (2007) also examined this fish population in the Madar Su after two floods in 2001-2002. Growth parameters were $L_\infty$ = 249 mm, K= 0.22 and $t_0$ = -0.30 for males and $L_\infty$ = 306 mm, K = 0.21 and $t_0$ = -0.38 for females. Length-weight relationships were W = -4.48 + 3.03TL for males and W = -4.59 + 3.0551TL in females, showing good feeding condition and positive isometric

growth. Males were smaller than females as they matured earlier. Male to female ratio was 1.5:1, significantly different. Age range was $1^+$ to $5^+$ for males and $2^+$ to $8^+$ years for females. The dominant age was $2^+$ years. Length was greatly decreased compared to previous studies and the population was younger, attributed to the floods. Abdoli *et al*. (2008) found fish identified as *Capoeta capoeta capoeta* from the Yasalegh Stream in the Gorgan River basin had a male to female ratio of 1:0.54, a maximum weight of 71.2 g for males and 119.4 g for females, and age range of 0-3 years, von Bertalanffy growth equations of $L_t = 190(1\text{-exp}\{-0.462\ [t+1]\}$ for males and $L_t = 230(1\text{-exp}\{-0.472\ [t+0.742]\}$ for females, and weight growth was isometric (*b* = 3.052 for males and 3.050 for females). Tilabad River fish had an age structure of 0-4 years and the Talar River 2-4 years, similar to Yasalegh Stream but differing from the Madar Su Stream. The fish in the latter stream had better living conditions in a national park, no pollution, no fishing, no competition from exotic carps, no other human disturbances, no environmental stress, and no food shortages. Gholizadeh *et al*. (2009) studied a population in the Zarrin Gol Stream in Golestan based on 100 fish, 39.9-148.8 m, and found age group $0^+$ was the most common at 59% and age groups $3^+$ and $4^+$ were the least common at 1%. Instantaneous growth of fish at age $3^+$ was much lower than younger age groups. The length-weight relationship was $W = 0.00003 \text{x} L^{2.822}$ and the von Bertalanffy equation was $L_t = 223.8\ (1\text{-exp}[0.185(t+1.8)]$. Shamekhi Ranjbar *et al*. (2012) found fish in the Dough (= Dogh) and Zarrin Gol streams to be 3-6 years old. Shamekhi Ranjbar *et al.* (2012a) back-calculated lengths at previous ages for a population in the Dough (=Dogh) Stream of the southeastern Caspian Sea basin; calculated lengths were smaller than observed lengths. Life span was 6 years. Patimar *et al*. (2009) found *b* values ranging from 2.647 (males at Chelchai, presumably Qal'eh) to 2.964 (females at Madar Su) indicating negative allometric growth for 1,731 fish (4.2-25.0 cm total length) from six localities in the Gorgan River basin. They interpreted this variation to the species' response to different habitat conditions. Shamekhi Ranjbar *et al.* (2012b, 2013) examined fish from five streams in the Gorgan River basin and found males to dominate (1.78:1), maximum relative abundance was 8.9-10.1cm for males and 7.7-8.9 for females, males were absent in the larger length groups, *b* values ranged from 2.90 for males of Pishkamer and Tilabad to 3.13 for females from Chelchai (presumably Qal'eh), and there were various differences between streams and sexes for length groups and abundance, attributed to differences in food resources, growth rates, and selection favouring larger size in some streams. Kor *et al*. (2017, 2018) examined 171 fish from the Zav River in Golestan National Park, finding maximum total length and weight were 19.9 cm and 122.43 g for females and 19.1 cm and 93.37 g for males, the length-weight relationship for females was $W = 0.0097TL^{3.11}$, for males was $W = 0.0142TL^{2.94}$ and the total relationship was $W = 0.0124TL^{3.0}$, showing positive allometric growth for females, negative allometric growth for males and isometric growth for the population. The condition factor was estimated to be 2.44 in males and 2.82 in females, and the total condition factor was 2.54.

Johari *et al*. (2010) found Talar River fish showed negative allometric growth in males and positive allometric growth in females. Age range was $0^+$ to $3^+$ years.

Patimar *et al*. (2011) examined fish from the Atrak River finding the population had a five-year life cycle (oldest males $4^+$ and females $5^+$, dominant age class $2^+$), length-weight relationships $W = 0.0127TL^{2.8981}$ for males, $W = 0.0083TL^{3.0998}$ for females and $W = 0.0084TL^{3.0942}$ for sexes combined (negatively allometric for males and positive for females and the population), $L_t = 22.11(1\text{-}e^{-0.19(t + 1.35)})$ for males, $L_t = 25.37(1\text{-}e^{-0.18(t + 1.25)})$ for females and $L_t = 24.92(1\text{-}e^{-0.18(t + 1.22)})$ for sexes combined, males grew faster than females, and females

dominated in the population (sex ratio 1:2.12).

In the Tajan River fish showed negative allometric growth with W = $0.0138L^{2.9123}$ (Patimar *et al*., 2012). Aazami *et al*. (2015b) gave a *b* value of 2.83 for 295 fish, 3.97-33.12 cm total length, from the Tajan River.

Zaherbin *et al*. (2013) examined fish from the Shirud and found a male:female sex ratio of 1:2.74, age range was 0-2 years for males and 0-4 years for females, with age group 2 dominant, the von Bertalanffy equation coefficients were $L_\infty$ = 31.3 mm, K = 0.2/year, $t_0$ = -0.4 years, and the length-weight relationship was isometric.

Esmaeili *et al*. (2014) gave a *b* value for 25 fish from the Caspian, 11.1-20.2 cm total length, as 2.84. Zareian *et al*. (2018a) gave a *b* value of 3.102 for 64 fish, 8.9-20.1 cm total length.

Heidari *et al*. (2014) found 40 fish above and below the Manjil and Tarik dams of the Sefid River attained an age of $4^+$ years. Heidari *et al*. (2014) gave *b* values of 2.939 and 2.861 for total and standard length for 40 fish from the Sefid River, indicating negative allometric growth. Ghasemzadeh-Sarcheshmeh *et al*. (2015) found 67 fish, 6.0-20.0 mm (*sic*, presumably cm) total length, from the downstream Sefid River had a *b* value of 3.045 for males and females combined, indicating positive allometric growth. Zamani Faradonbeh *et al*. (2015) found a *b* value of 3.116 (positive allometric growth) and a condition factor of 0.911 for 240 fish, 25.9-145.9 mm total length, from the Tutkabon River. Ghasemzadeh-Sarcheshmeh *et al*. (2018) examined 320 fish, 5.6-23.5 cm total length for mature fish, from the Sefid River and found a female:male sex ratio of 1:2.63, and mature males and females were longer than 8.8 and 14.8 cm in total length and $1^+$ and $2^+$ in age respectively. Most fish were $2^+$ and $3^+$ years old. Maximum age was $5^+$ years. Mousavi-Sabet *et al*. (2018a) examined length-weight relationships for three populations totalling 439 fish, 3.9-23.5 cm total length, from upstream and from downstream of the Manjil and Tarik dams on the Sefid River, along with 331 fish from the Tutkabon Stream as a control independent from the dams. Adults had a sex ratio of 1:1. *b* values were 2.893 and 2.939 for downstream and upstream populations, and 3.586 for the dam lake where average total length was 17.51 cm versus 9.24 cm and 9.99 cm in downstream and upstream populations. The control population was 2.735. The dam lake had positive allometric growth while the others had negative allometric growth. These differences were attributed to the low primary productivity of shallow, muddy and free-flowing rivers compared to the dam lake. Separation by dams may have also affected fish morphology and so growth parameters. Sex and maturity also affected growth patterns. Ponnazar *et al*. (2018) found fish from the Shah River at Lushan had positive allometric growth in males and negative allometric growth in females.

Pahlavani *et al*. (2015) studied 224 fish in the Babol River and found age groups 0 to 4 years with most (39.7%) in age group 3.

Zamani Faradonbe *et al*. (2015) found a *b* value of 2.96 and a condition factor (K) of 0.833 for 33 fish (8.54-20.24 cm total length) from the Taleghan (= Taleqan) River, Alborz Province.

Rahimibashar *et al*. (2016) examined fish from the Shafa River and found a male:female sex ratio of 1.02:1, age classes $0^+$ to $5^+$ with a mean age of 2.41 years, age $2^+$ fish the most abundant and age $5^+$ fish the least abundant, the length-weight relationship was W = $0.014TL^{0.975}$ (*sic*, presumably *b* = 2.975, isometric growth), growth efficiency (k) was 0.92 and $L_\infty$ was 17.22 cm.

Asadi *et al*. (2017) gave a *b* value of 2.723 for 195 fish (24-131 mm total length) from

the Shahrbijar River, Gilan with a total length condition factor of 1.06 (as *C. gracilis*).

**Food.** In the Talar and Yasalegh rivers of the eastern Caspian Sea basin, 27 genera of phytoplankton were identified in the diet, with Chrysophyta being dominant, but with some differences between older and younger fish in the species consumed (Mostafavi and Abdoli, 2005). Gholizade *et al*. (2009) found fish from the Zarrin Gol Stream (a Gorgan River tributary) fed mainly on periphyton, 97% being Chrysophyta and the rest being Chlorophyta, Cyanophyta and Euglenophyta. While diet was mainly herbivorous, some macrobenthos and aquatic larvae were taken such as Diptera. Rahimibashar *et al*. (2017) examined 418 fish from five stations in the Shafa River and found the mean obesity coefficient, relative length index of gut, condition factor (K), index of fullness and vacuity index were 1.32, 38.67, 8.49 and 465.78 respectively (*sic*). The diet was decayed plants, algae, periphyton, and insignificant amounts of aquatic insects (often larvae.

**Reproduction.** Fish caught on the 7 July 1978 (CMNFI 1979-0490) had eggs up to 1.6 mm in diameter while fish caught as early as 30 November 1961 had eggs evidently developing (CMNFI 1970-0525).

Rezaei *et al*. (2007) found no change in reproductive characteristics after floods in the Madarsoo (= Madar Su) Stream population. Mean fecundity was 3,116 eggs and the maximum gonadosomatic index was in June. Shajiee *et al*. (2009) found a maximum gonadosomatic index for Tajan River fish in April and May when spawning occurred, with maximum gonadosomatic indices in males at ages 3-4 years and in females at 2-3 years. Patimar *et al*. (2011) found fish from the Atrak River had a reproductive season from April to July, peaking in May for males and April for females, absolute fecundity reached 5,743 eggs, relative fecundity 132.58 eggs/g and egg diameter 2.4 mm. Rasta *et al*. (2011) and Khodadoust *et al*. (2013a) found two- to four-year-old fish from the Sefid River had an average absolute fecundity of 1,572.6 eggs, an average relative fecundity of 19.51, and a maximum egg diameter of 1.16 mm. The oldest fish had the maximum average absolute fecundity (2,355.27 eggs) and maximum average relative fecundity (22.5) was in two-year-olds. Khodadoust *et al*. (2013b) found no significant differences in the gonadosomatic index in one-, two- and three-year-old fish from the Sefid River, although naturally length, weight and gonad weight varied. Shamekhi Ranjbar *et al*. (2012) found fish in the Dough (= Dogh) and Zarrin Gol streams to have an average absolute fecundity of 6,030 and 5,512 eggs respectively, the variation assumed to be different responses to different habitats. Absolute fecundity reached 9,875 eggs and 12,107 eggs, relative fecundity 336 eggs/g and 252 eggs/g, with a maximum egg diameter of 1.03 mm and 1.18 mm. Zaherbin *et al*. (2013) examined fish from the Shirud and found total absolute fertility of 3,562.56 eggs, a range in egg diameter of 0.3-2.3 mm, and gonad development peaking in March and April. Pahlavani *et al*. (2015) studied 224 fish in the Babol River and found a mean egg diameter of 0.76 mm, absolute fecundity 3,603 eggs and relative fecundity 65.56 eggs/g. Kor *et al*. (2017, 2018) examined 171 fish identified as *C. gracilis* from the Zav River in Golestan National Park, finding a significantly different male:female sex ratio of 1.67:1, the highest mean gonadosomatic index was observed for females in March and males in May (April and June in the 2018 paper), 4.75 and 7.51 respectively, the minimum, maximum and average absolute fecundity were 7,300, 41,736 and 18,062.4 (17,978 in the 2018 paper), while those of the relative fecundity (eggs/g) were 241, 4,883 and 1,341.42 (1,434.06 in the 2018 paper) respectively, and egg diameters ranged from 0.10 to 0.98 mm with a mean value of 0.44 mm. Ghasemzadeh-Sarcheshmeh *et al*. (2018) examined 320 fish from the Sefid River and found spawning took place from late May to late August when water temperatures

were between 19.7 and 22.8ºC. At the beginning of the reproductive period, the average gonadosomatic index was 10.0%, with a range of 4.03-15.9%, in ripe females. Ripe males were ready to spawn earlier than females. The average egg diameter was 0.99 mm, range 0.2-2.3 mm. The average absolute and relative fecundities were 4,386 eggs (range 1,777-8,315 eggs) and 66.3 eggs/g (range 20-186 eggs/g).

**Parasites and predators.** The following records of parasites occurred under the names *C. capoeta* or *C. c. gracilis* and are presumed to be *C. razii* by distribution. Molnár and Jalali (1992) recorded the monogeneans *Dactylogyrus chramulii*, *D. gracilis* and *D. lenkorani* in the Sefid River, *D. lenkorani* in the Tonekabon and Tajan rivers, and *D. pulcher* from the Sefid, Tajan, Tonekabon and "Ghasemlu" rivers of the Caspian Sea basin. Malek (1993) and Malek and Mobedi (2001) reported *Clinostomum complanatum* from fish in the Shirud, Mazandaran. Up to 60 parasites per fish were recorded, with female fish having the highest infestation (the later study showing no difference between male and female fish), infestation decreasing with increase in body length, and parasites being concentrated in the gill cavity and pharynx. Shamsi *et al*. (1997) reported *Clinostomum complanatum*, a parasite causing laryngo-pharyngitis in humans, from the Shirud, the highest rate in nine species examined. Masoumian and Pazooki (1998) surveyed myxosporeans in this species in Gilan and Mazandaran provinces, finding *Myxobolus musayevi* and *M. samgoricus*.

Masoumian *et al*. (2002) found the protozoan *Myxobolus musayevi* in fish in the Tajan River in Mazandaran. Mokhayer *et al*. (2000, 2000) reported *Acanthocephalorhynchoides cholodkowskyi* (Quadrigyridae) from the midgut and *Tracheliastes polycolpus* (Lernaeopodidae) on the fins of this fish in Golestan National Park, with more parasites on male fish and differences by season and station. Naem *et al*. (2002) found parasites on the gills of this species from the western branch of the Sefid River, namely the protozoan *Trichodina* sp. and the monogenean trematode *Dactylogyrus lenkorani*. Rohei Aminjan and Malek (2004) found nine parasite species in fish from the Shirud, the trematodes *Allocreadium* sp., *Clinostomum complanatum*, *Diplostomum spathaceum*, *Posthodiplostomum cuticola*, the monogeneans *Dactylogyrus pulcher*, *D. lenkorani*, *Gyrodactylus mutabilitas* and the nematodes *Capillaria* sp. and *Rhabdochona fortunatowi*. Pazooki *et al*. (2005) recorded *Tracheliastes longicollis, Lamprolegna compacta*, *Neoechinorhynchus rutili*, *Capillaria* sp., *Myxobolus musajevi*, *M. cristatus*, *Trichodina perforata*, *Chilodonella piscicola*, *Ichthyophthirius multifilis* and *Ichthyobodo necatrix* from this species in waterbodies of Zanjan Province. Pazooki *et al*. (2006) recorded the monogeneans *Dactylogyrus chramuli, D. gracilis, D. lamellatus, D. lenkorani, D. pulcher* and *Gyrodactylus* sp. from this fish in Zanjan Province. Maleki and Malek (2007) examined fish from the Shirud in the Caspian Sea basin and recorded the digeneans *Allocreadium* sp., *Diplostomum spathaceum*, *Clinostomum complanatum* and *Posthodiplostomum cuticola*. Hassan *et al*. (2008) reported the nematode *Hepaticola petruschewkii* from fish in the Babol and Tajan rivers. Miar *et al*. (2008) examined fish in Valasht Lake and the Chalus River, Mazandaran and found the metazoan *Myxobolus saidovi*. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Lamproglena compacta* and *Tracheliastes longicollis* on this species. Gholami *et al*. (2009) examined fish from the Neka River and found the protozoan *Ichthyophthirius multifilis*, the metazoans *Diplozoon* sp., *Dactylogyrus* sp. and *Gyrodactylus* sp. and the nematode *Raphidascaris acus*.

Golestaninasab *et al*. (2012) recorded the nematode *Rhabdochona fortunatowi* in fish from the Shirud in the Caspian Sea basin, infection varying with season and host size but not host sex. Anvarifar *et al*. (2014) recorded the variations in occurrence and intensity of

*Tracheliastes polycolpus*, a copepod ectoparasite, in the Tajan River. Hosseinifard *et al*. (2014) recorded *Dactylogyrus*, *Diplozoon* and various nematodes from this fish in the Garmrud at Amol, Mazandaran. Mazaheri Kohanestani *et al*. (2014, 2014) recorded the digenean *Posthodiplostomum cuticola* in fish from the Zarrin Gol Stream in Golestan Province and the fish had a significantly lower condition factor. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Neoechinorhynchus rutili* (Golestan Park River and Zanjan Province), *Neoechinorhynchus* sp. (Sefid River) and *Pallisentis cholodkowskyi* (Golestan Park River). Hosseinifard *et al*. (2017) recorded the following parasites from fish in the Chalus River - *Ichthyophthirius multifiliis*, *Myxobolus* sp., *Dactylogyrus lenkorani*, *Gyrodactylus prostae*, *Allocreadium* sp. and *Rhabdochona hellichi*. Mazaheri Kohanestani *et al*. (2017) found fish from the Zarrin Gol Stream in Golestan infected with *Posthodiplostomum cuticola* responded through stimulation of erythropoietic cells and the immune system. Taheri Mirghaed *et al*. (2017) recorded parasites from fish in the Alborz Dam and Babol River in Mazandaran, namely *Trichodina gracilis* (river) (Ciliophora), *Dactylogyrus lenkorani* (dam and river), *Gyrodactylus gobioninum* (river) and *G. prostae* (river) (Monogenea), and *Ligula intestinalis* (dam) (Digenea). Barzegar *et al*. (2018) reported the monogeneans *Gyrodactylus gobioninum*, *G. katharineri*, *G. mutabilitas* and *G. sprostonae* from fish identified as *C. capoeta* from the Talar and Babol rivers, Talar and Tonekabon rivers, Babol River and Babol, Tajan and Talar rivers respectively in Mazandaran.

**Economic importance.** A widespread and significant species in Caspian Sea drainages of Iran. Jafari *et al*. (2018) investigated the growth and feasibility of using *C. capoeta gracilis* (presumably *C. razii*) in aquaculture. Fish fed at 4% of body weight showed growth suitable for aquaculture.

**Experimental studies.** The following studies appeared under the names *C. capoeta* and *C. c. gracilis* but are presumably *C. razii* by distribution. Banagar *et al*. (2011) reported concentrations of cadmium in liver and muscle tissue for fish from the Tajan River higher than standard limits set by the World Health Organization and Banagar *et al*. (2013) found copper levels in liver were the same. Malvandi *et al*. (2014) examined total mercury in muscle tissue of fish from the Cheshmeh Kileh (= Tonekabon) and Zarrin Gol rivers, the former being significantly higher at 249 ng $g^{-1}$ dw as opposed to 164 ng $g^{-1}$ dw but both represent a negligible risk for human health. Shiry *et al*. (2015) evaluated cholinesterase activity as a biomarker for environmental monitoring in the Gorgan River basin, detecting pesticide usage. Soltani *et al*. (2015) found that nanoparticles of zinc had fewer adverse effects than zinc sulphate as seen in histopathological gill lesions. Mollazadeh and Mirsajjadi (2016) studied cadmium and zinc levels in fish from the Sardab River in Mazandaran finding more in liver than muscle tissue, variation in levels between sample stations, and muscle levels within acceptable international limits. Fish exposed to butachlor pesticide had a lethal concentration of 2.46 mg/l, showed lesions of the gills and liver, and could be used as a biomarker for this pollutant (Forouhar Vajargh *et al*., 2019).

Rameshgar *et al*. (2020) isolated and identified *Lactobacillus brevis* and *L. plantarum* with probiotic potential from the intestinal tract of this species.

Yousefzade *et al*. (2012a) listed haematological parameters in fish from the Talar River and found no differences between sexes and ages. Yousefzade *et al*. (2012b), however, examined fish from the Siah River and found significant differences in such blood serum parameters as calcium, cholesterol and sodium rate, associated with age. Yousefzadeh *et al*. (2014) compared cellular and biochemical blood factors between fish in the breeding season

from the Talar and Siah rivers, finding differences attributed to environmental conditions. Knowledge of blood parameters is useful in aquaculture. Yousefzadeh and Khara (2015) found differences in sodium and potassium levels among ages (one-, two-, three- and four-year-old fish from the Siah and Talar rivers) and between localities for white and red blood cell counts, haemoglobin and eosinophil levels, information useful in monitoring health of field-collected fish.

**Conservation.** Kiabi *et al*. (1999) considered this species, identified as *Capoeta capoeta gracilis*, to be of least concern in the south Caspian Sea basin according to IUCN criteria. Criteria included sport fishing, abundant in numbers, habitat destruction, widespread range (75% of water bodies), present in other water bodies in Iran, and present outside the Caspian Sea basin (last two not true as now *C. razii*). Aliakbarian *et al*. (2014) examined the genetic variation and population structure of fish identified as *Capoeta capoeta gracilis* from the Madar Su and Gorgan rivers, useful for management and conservation programmes. Listed as of Least Concern by the IUCN (2015) as *C. capoeta*. Jouladeh-Roudbar *et al*. (2020) listed this widespread Caspian species as of Least Concern.

**Sources**. Jouladeh-Roudbar *et al*. (2017) for redefinition of fish formerly referred to *C. capoeta*, *C. c. gracilis* or *C. gracilis* in the Iranian Caspian Sea basin (except Aras River populations now referred to *C. capoeta*).

Iranian material:- CMNFI 1970-0506, 103, not kept, Gilan, Shalman River (37º08'N, 50º15'E); CMNFI 1970-0511, 6, not kept, Gilan, Shafa River estuary (37º35’N, 49º09’E); CMNFI 1970-0512, 3, 33.6-52.2 mm standard length, Gilan, Shalman River (37º08'N, 50º15'E); CMNFI 1970-0513, 5, not kept, Gilan, Shafa River estuary (37º35'N, 49º09'E); CMNFI 1970-0514, 17, 37.9-61.2 mm standard length, Gilan, Shafa River estuary (37º55'N, 49º09'E); CMNFI 1970-0515, 38, not kept, Gilan, Shafa River estuary (37º35'N, 49º09'E); CMNFI 1970-0516, 6, 50.1-62.6 mm standard length, Gilan, Lomir River (38º14'N, 48º52'30"E); CMNFI 1970-0517, 10, 41.7-63.9 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1970-0518, 37, not kept, Gilan, Haviq River estuary (38º10'N, 48º54'E); CMNFI 1970-0519, 2, 39.1-45.0 mm standard length, Gilan, Chelvand River (ca. 38º18'N, ca. 48º52'E); CMNFI 1970-0520, 7, 50.8-100.9 mm standard length, Gilan, Astara River (ca. 38º25'N, ca. 48º52'E); CMNFI 1970-0521, 3, 38.9-101.4 mm standard length, Gilan, Sefid River near Lulaman (no other locality data); CMNFI 1970-0522, 10, 35.1-45.1 mm standard length, Gilan, Sefid River at Astaneh Bridge (37º16'30"N, 49º56'E); CMNFI 1970-0525, 5, 92.8-146.1 mm standard length, Gilan, Sefid River near Mohsenabad (ca. 37º22'N, ca. 49º57'E); CMNFI 1970-0526, 8, 30.9-84.6 mm standard length, Gilan, Sefid River below Astaneh Bridge (37º19'N, 49º57'30"E); CMNFI 1970-0531, 7, 60.2-84.6 mm standard length, Mazandaran, Larim River (36º46'N, 52º58'E); CMNFI 1970-0536, 5, 101.4-125.4 mm standard length, Gilan, Siah River estuary near Rudbar (36º53'N, 49º32'E); CMNFI 1970-0537, 13, not kept, Gilan, Shah River above Manjil Dam (36º44'N, 49º24'E); CMNFI 1970-0538, 5, 95.4-231.9 mm standard length, Gilan, Qezel Owzan River above Manjil Dam (36º44'N, 49º24'E); CMNFI 1970-0546, 1, 66.2 mm standard length, Gilan, Sefid River canal (no other locality data); CMNFI 1970-0568, 9, 31.4-84.8 mm standard length, Gilan, Caspian Sea at Kazian Beach (ca. 37º29'N, ca. 49º29'E); CMNFI 1970-0577, 1, not kept, Gilan, Caspian Sea at Astara (ca. 38º26'N, ca. 48º53'E); CMNFI 1970-0583, 8, 34.1-93.9 mm standard length, Gilan, Nahang Roga River (37º28'N, 49º28'E); CMNFI 1979-0084, 1, 138.6 mm standard length, Mazandaran, Chalus River (no other locality data); CMNFI 1979-0429, 1, 34.3 mm standard length, Mazandaran, Chalus River (36º34'N, 51º23'E); CMNFI 1979-0430, 13, 17.5-61.9 mm

standard length, Mazandaran, river 1 km east of Now Shahr (36º39'N, 51º31'E); CMNFI 1979-0432, 1, 54.9 mm standard length, Mazandaran, Sardab River branch (36º41'N, 51º22'E); CMNFI 1979-0433, 1, 115.2 mm standard length, Mazandaran, stream 18 km west of Chalus (36º42'N, 51º15'E); CMNFI 1979-0434, 1, 45.5 mm standard length, Mazandaran, Shirud River (36º51'N, 50º49'E); CMNFI 1979-0435, 1, 22.8 mm standard length, Gilan, stream west of Ramsar (36º57'N, 50º37'E); CMNFI 1979-0438, 2, 142.4-144.8 mm standard length, Gilan, Gholab Ghir River (37º27'N, 49º37'E); CMNFI 1979-0441, 1, 121.9 mm standard length, Gilan, river 14 km south of Hashtpar (37º42'N, 48º58'E); CMNFI 1979-0443, 1, 53.2 mm standard length, Gilan, river 34 km west of Hashtpar (38º06'N, 48º53'E); CMNFI 1979-0444, 1, 58.9 mm standard length, Gilan, Chubar River (38º11'N, 48º52'30"E); CMNFI 1979-0446, 1, 29.0 mm standard length, Gilan, Astara River (38º26'30"N, 48º51'E); CMNFI 1979-0449, 2, 87.4-97.9 mm standard length, Ardabil, river 18 km from Khalkhal (ca. 37º42'N, ca. 48º27'E); CMNFI 1979-0451, 30, 35.8-97.3 mm standard length, East Azarbayjan, Qezel Owzan River (ca. 37º30'N, ca. 47º57'E); CMNFI 1979-0452, 1, 79.7 mm standard length, East Azarbayjan, Qezel Owzan River 6 km from Mianeh (37º23'N, 47º45'E); CMNFI 1979-0453, 24, 36.1-111.1 mm standard length, Zanjan, Zanjan River (37º06'N, 47º56'E); CMNFI 1979-0469, 2, 56.6-76.2 mm standard length, Mazandaran, river 36 km west of Alamdeh (36º37'30"N, 51º35'E); CMNFI 1979-0474, 1, 125.1 mm standard length, Mazandaran, Tajan River (36º34'N, 53º05'E); CMNFI 1979-0475, 1, 86.4 mm standard length, Golestan, stream on road to Gorgan (36º46'N, 54º00'E); CMNFI 1979-0480, 2, 33.3-44.2 mm standard length, Golestan, Gorgan River at Gonbad-e Kavus (37º15'30"N, 55º09'E); CMNFI 1979-0481, 3, 101.9-188.0 mm standard length, Golestan, stream 3 km west of Ghalahleekesh (37º18'30"N, 55º31'E); CMNFI 1979-0482, 2, 117.8-191.8 mm standard length, Golestan, river between Minudasht and Dowlatabad (37º19'30"N, 55º31'E); CMNFI 1979-0483, 4, 121.6-160.5 mm standard length, Golestan, Cheshmeh River (37º23'30"N, 55º51'30"E); CMNFI 1979-0484, 3, 149.0-172.2 mm standard length, North Khorasan, stream on road to Bojnurd (37º28'N, 56º44'E); CMNFI 1979-0485, 3, 71.2-99.1 mm standard length, North Khorasan, stream 28 km west of Bojnurd (37º33'N, 57º04'E); CMNFI 1979-0486, 66, 17.5-97.8 mm standard length, North Khorasan, stream in Atrak River drainage (37º44'N, 56º18'E); CMNFI 1979-0487, 20, 20.4-35.6 mm standard length, Golestan, spring 2 km from Maraveh Tappeh (37º54'N, 55º58'E); CMNFI 1979-0488, 9, 29.7-140.4 mm standard length, Golestan, Atrak River at Maraveh Tappeh (37º55'N, 55º57'30"E); CMNFI 1979-0489, 78, 22.1-154.4 mm standard length, Golestan, stream 13 km from Maraveh Tappeh (37º50'N, 55º53'E); CMNFI 1979-0490, 14, 21.0-108.4 mm standard length, Golestan, stream in Gorgan River drainage (ca. 37º39'N, ca. 55º42'E); CMNFI 1979-0491 2, 115.8-146.3 mm standard length, Golestan, Gorgan River 15 km northeast of Kalaleh (ca. 37º33'N, ca. 55º44'E); CMNFI 1979-0492, 25, 9.3-183.4 mm standard length, Golestan, Tilabad River in Gorgan River drainage (37º05'N, 55º15'E); CMNFI 1979-0589, 9, 95.8-140.0 mm standard length, Gilan, Sefid River opposite Kisom (37º12'N, 49º54'E); CMNFI 1979-0626, 1, 47.0 mm standard length, Gilan, Sefid River (no other locality data); CMNFI 1979-0692, 27, 20.1-60.6 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1979-0695, 13, 77.6-179.0 mm standard length, Gilan, Sefid River at Manjil Bridge (36º46'N, 49º24'E); CMNFI 1980-0116, 1, 95.1 mm standard length, Gilan, Sefid River at Astaneh Bridge (37º16'30"N, 49º56'E); CMNFI 1980-0120, 1, 54.0 mm standard length, Mazandaran, Babol River at Babol Sar (36º43'N, 52º39'E); CMNFI 1980-0121, 2, 125.2-131.9 mm standard length, Gilan, Shafa River estuary (37º35'N, 49º09'E); CMNFI 1980-0123, 1, 86.2 mm standard length, Gilan, Sefid River around Dakha (ca. 37º22'N, ca. 49º57'E);

CMNFI 1980-0131, 2, 65.5-80.3 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0132, 7, 24.5-134.6 mm standard length, Gilan, Sefid River at Kisom (37º12'N, 49º54'E); CMNFI 1980-0141, 5, 38.4-54.8 mm standard length, Gilan, Lisar River estuary (37º59'N, 48º56'E); CMNFI 1980-0143, 1, 110.0 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0490, 2, 84.1-102.0 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0491, 13, 40.6-65.8 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0906, 7, 82.7-124.4 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1991-0163, 2, 57.6-75.4 mm standard length, Golestan, Ramian River (36º58'N, 55º07'E); CMNFI 2007-0106, 9, 62.7-90.6 mm standard length, Kordestan, Qezel Owzan River basin near Divan Darreh (ca. 35º52'N, ca. 47º05'E); CMNFI 2007-0107, 10, 49.4-198.0 mm standard length, Kordestan, Qezel Owzan River basin near Bijar (ca. 35º54'N, ca. 47º20'E);

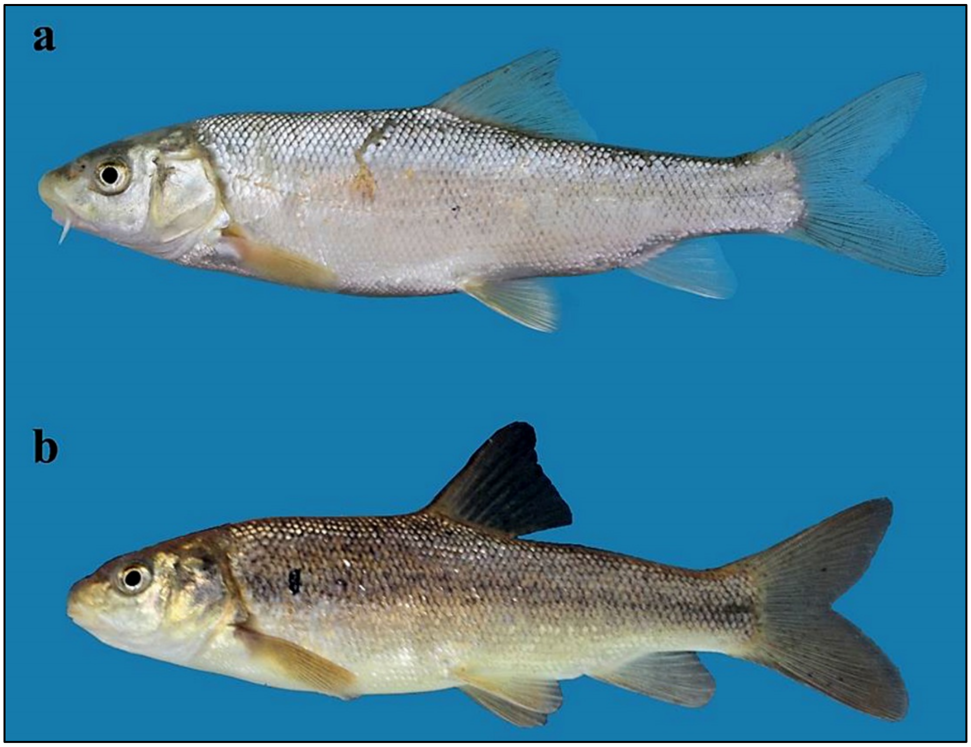
***Capoeta saadii***
(Heckel, 1847)

*Capoeta saadii*, Fars, Kor River, after Alwan (2010).

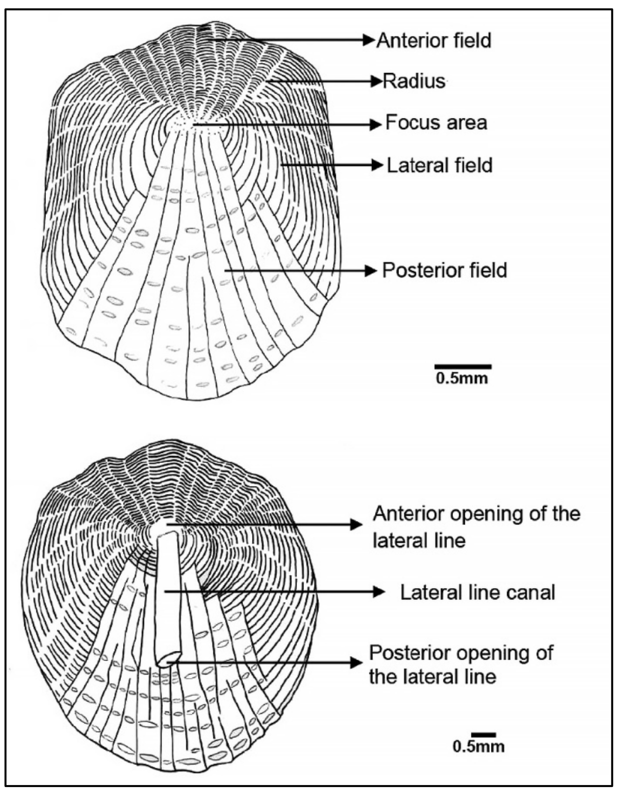
*Capoeta saadii*, CMNFI 1979-0309, Kerman, Fahraj River at Azizabad,
30 November 1977, Brian W. Coad.

*Capoeta saadii*, 168.7 mm standard length, CMNFI 1979-0115, Sa`di's Tomb, 24 June 1976, Brian W. Coad.

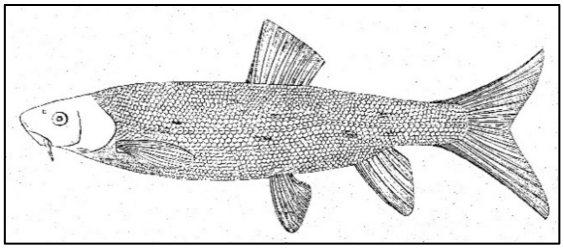
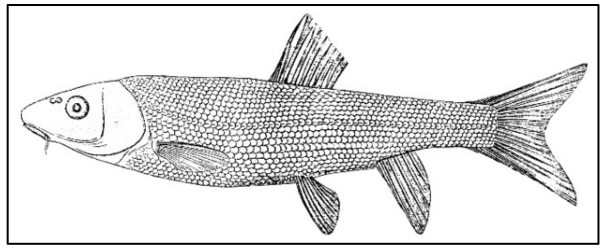
*Capoeta saadii*, ventral head, CMNFI 1979-0115, Brian W. Coad.



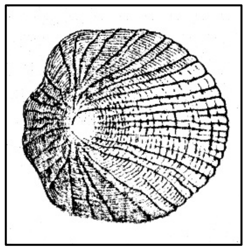
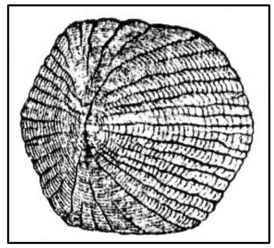

*Capoeta saadii*, a) Fars, Kor River, b) Fars, Malousjan Spring, Hamid Reza Esmaeili.




*Capoeta saadii*, scale from between dorsal fin and lateral line above, and lateral line scale below, Azad Teimori.

*Scaphiodon chebisiensis* and *S. rostratus*, after Keyserling (1861).

*Scaphiodon chebisiensis* and *S. rostratus*,
flank scales, after Keyserling (1861).

**Common names.** Siyah mahi Saadi, siah mahi Saadi.

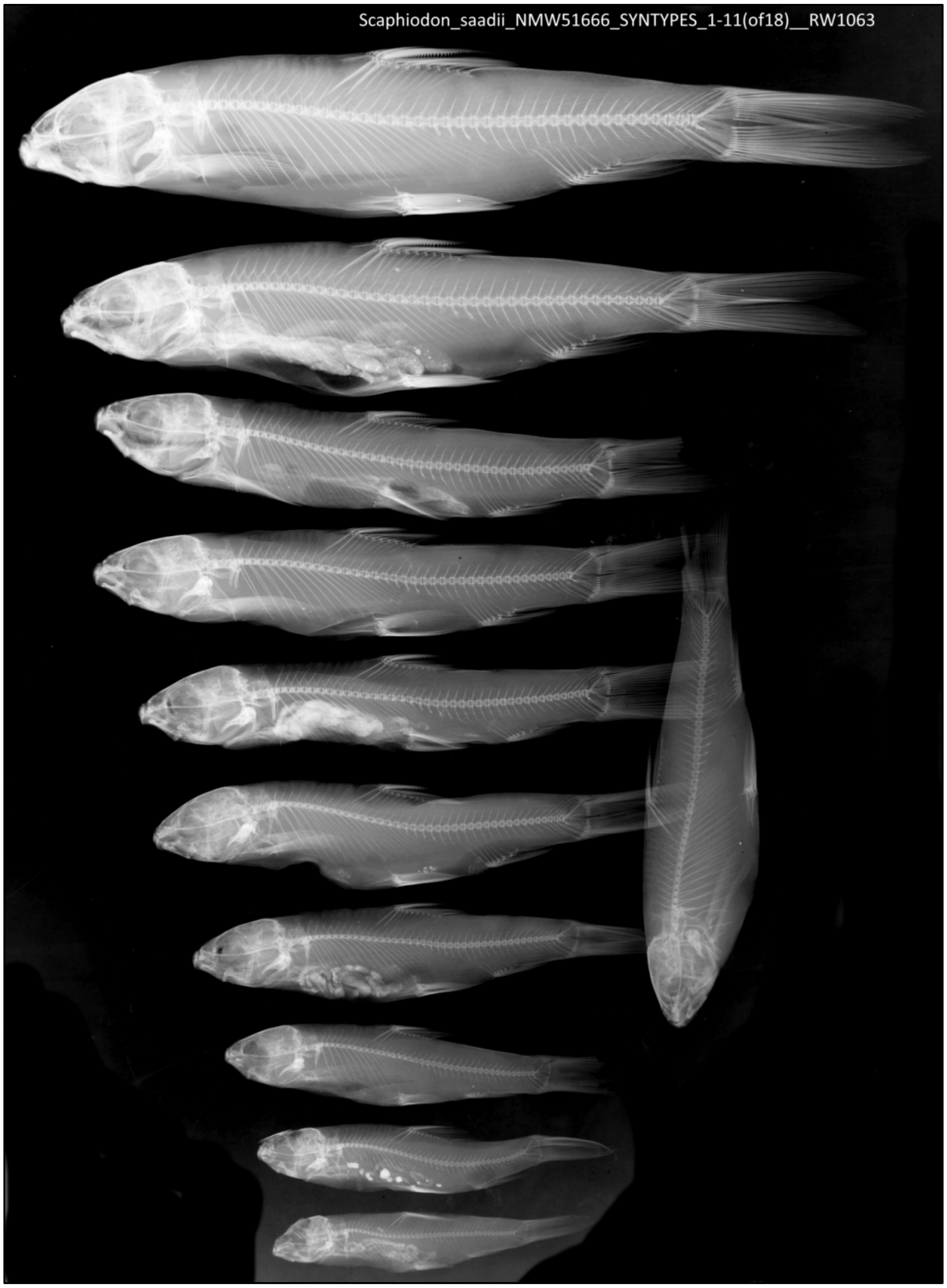
[Saadi scraper].

**Systematics.** This species was formerly identified as *C. damascina* and much of the literature appears under that name. *Scaphiodon Saadii* Heckel, 1847 was described from the "Quellen des Saadi" (Sa`di at 29°37'N, 52°35'E, now within the city of Shiraz) and the "Nähe von Persepolis" (= probably the Pulvar (= Sivan) River near Persepolis, Fars). Synonyms are *Scaphiodon Amir* Heckel, 1847 described from the "Araxes" (= Kor River, Fars), *Scaphiodon niger* Heckel, 1847 described from the "Araxes oder Benth-Amir" (= Kor River, also known as the Band-e Amir River), *Scaphiodon chebisiensis* Keyserling, 1861 from "Wasserleitung in Chebis" (= canal in Chebis, probably Khabis or Shahdad at 30°25'N, 57°42'E in Kerman and as Wasserleitung may also be translated as water conduit and aqueduct and this could refer to a qanat stream as canals in the European sense were not present in Iran), *Scaphiodon rostratus* Keyserling, 1861 from "Wasserleitungun in der Umgegend von Jezd. Das abgebildete Exemplar stammte aus Meibut" (= canals in the vicinity of Yazd and see above for Wasserleitung. The pictured copy came from Meibut). This latter is probably Meybod at 32°14'N, 54°01'E.

Fifteen syntypes in the catalogue (18 seen by me and in the Vienna card index in 1997 and in Alwan (2010)) of *Scaphiodon saadii* from Sa`di are under NMW 51666 (Eschmeyer *et al*. (1996) had 52666, apparently in error) and measure 58-123 mm standard length (18.3-123.8 mm standard length when measured by me) with a further four syntypes from Persepolis under NMW 55900 measuring 84-114 mm standard length (Kähsbauer, 1964; not in the 1997 card index). There is also one syntype (RMNH 3166) in the Rijksmuseum van Natuurlijke Historie, Leiden from NMW (Eschmeyer *et al*., 1996).


*Scaphiodon saadii*, syntypes, NMW 51666, Naturhistorisches Museum, Wien.


*Scaphiodon saadii*, syntypes, NMW 51666, Naturhistorisches Museum, Wien.




*Scaphiodon saadii*, syntypes, NMW 51666, Naturhistorisches Museum, Wien.

Eight fish listed as syntypes of *Scaphiodon amir* are under NMW 46081 (6) and NMW 16508 (1, dried) as did the *Catalog of Fishes* which adds one fish under RMNH 2682 (Rijksmuseum van Natuurlijke Historie, Leiden, ex NMW).

*Scaphiodon amir*, syntype, NMW 16508, Naturhistorisches Museum, Wien.

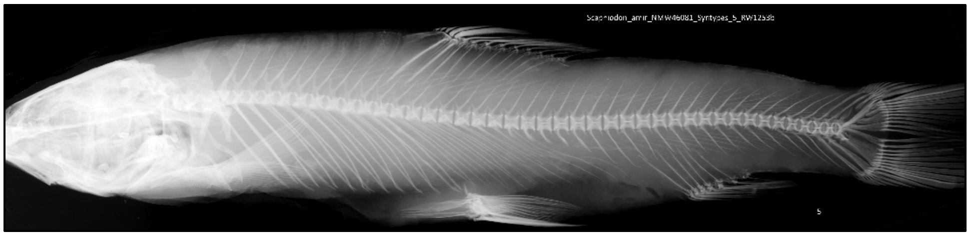
*Scaphiodon amir*, syntypes, NMW 46081, Naturhistorisches Museum Wien.

*Scaphiodon amir*, syntypes, NMW 46081, Naturhistorisches Museum Wien.


*Scaphiodon amir*, syntypes, NMW 46081, Naturhistorisches Museum, Wien.

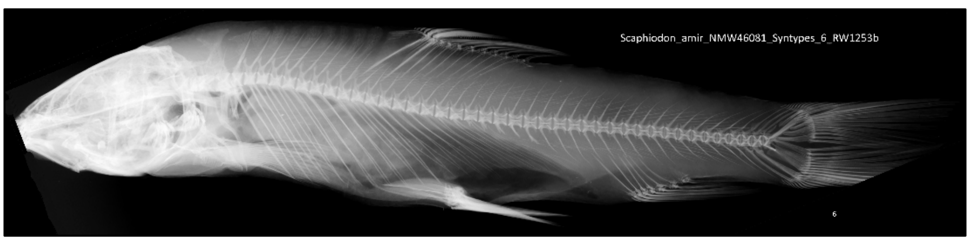

*Scaphiodon amir*, syntypes, NMW 46081, Naturhistorisches Museum Wien.


*Scaphiodon amir*, syntype, NMW 46081, Naturhistorisches Museum, Wien.



*Scaphiodon amir*, syntype, NMW 46081, Naturhistorisches Museum Wien.

*Scaphiodon amir*, syntype, NMW 46081, Naturhistorisches Museum, Wien.

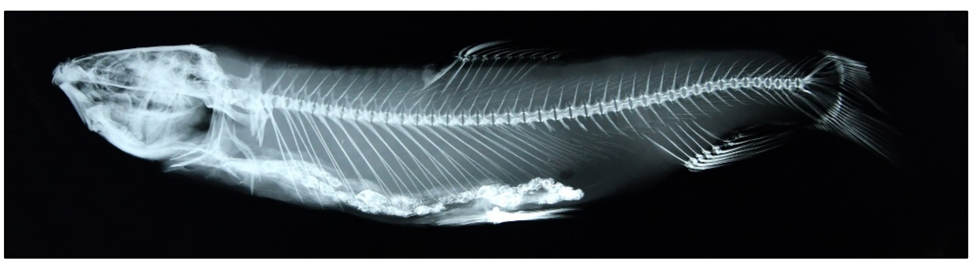



*Scaphiodon amir*, syntype, NMW 46081, Naturhistorisches Museum Wien.

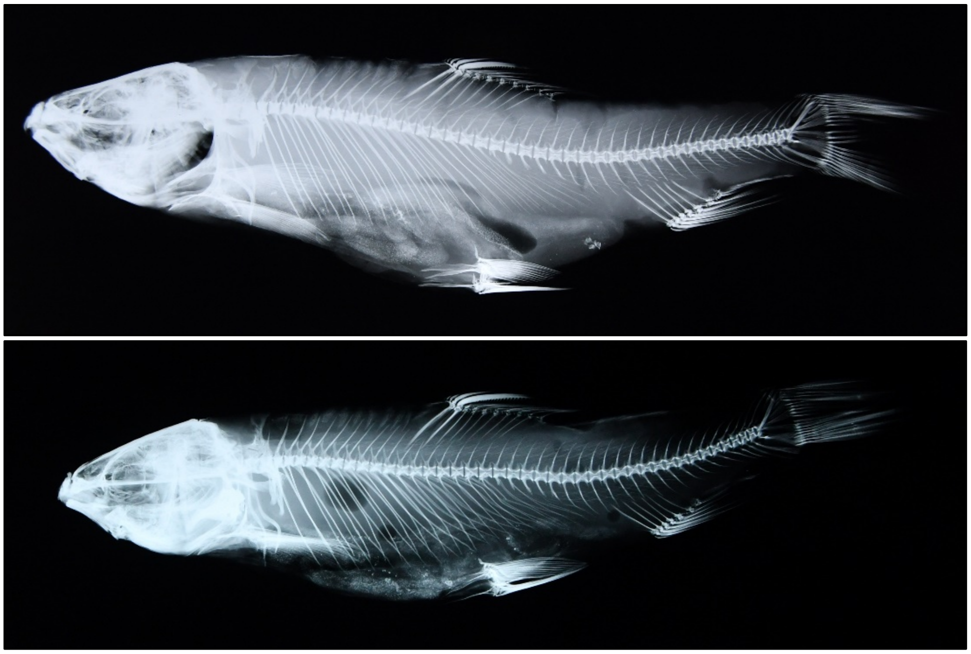
Two syntypes of *Scaphiodon niger* are in the Naturhistorisches Museum Wien under NMW 51655 with standard lengths of 140.4 and 188.5 mm (another syntype is under NMW 51654 (232.7 mm), and a fourth under NMW 51656 as seen by me (221.7 mm standard length in Alwan (2010)); all four are listed as syntypes in the 1997 Vienna card index).


*Scaphiodon niger*, syntype, NMW 51656, Naturhistorisches Museum, Wien.


*Scaphiodon niger*, syntype, NMW 51656,
Naturhistorisches Museum, Wien.



*Scaphiodon niger*, syntype, NMW 51654, Naturhistorisches Museum, Wien,
Brian W. Coad.



*Scaphiodon niger*, syntypes, NMW 51655, Naturhistorisches Museum, Wien,
Brian W. Coad.

The catalogue in Vienna listed no fish opposite the name *S. niger*, 6 and 2 fish in one column and 5 in the adjacent column for *Scaphiodon amir* (*cf*. above), 10 fish in one column and 10 in the adjacent column for *S. saadii* (*cf*. above).

Bianco and Banarescu (1982) recognised *Capoeta saadii* as a distinct species based on an arched mouth rather than transverse as in most subspecies of fish then recognised as *Capoeta capoeta*, with a lightly developed horny cover on the lip, a feebly ossified dorsal fin spine, 13-17 gill rakers, modally 8 dorsal fin branched rays, 53-76 lateral line scales and 24-28 scales around the caudal peduncle. However, they do point out the extreme variability in scale counts, for example, from fish taken in the same locality and even between opposite sides of the same fish (5 more scales on one side than the other!). Designation of subspecies on such variable characters is difficult and would require very large series and multivariate analysis techniques. Bianco and Banarescu (1982) regarded *C. c. intermedia* (probably *C. mandica*) as intermediate between *C. c. umbla* and their *C. c. macrolepis* on the basis of scale counts, gill raker counts, smaller transverse mouth than in *umbla*, and a rather light colouration.

Shojaie *et al*. (2021) studied 20 morphological traits in 15 specimens from each of the Maharlu River (Maharlu Lake basin), the Shapur River (Persis basin) and the Kor River (Kor River basin) and found the populations were significantly different in eight traits. Body depth was the most effective character to discriminate the populations. Cluster analysis separated the Shapur population from the others.

**Key characters.** This species is distinguished from other small-scaled *Capoeta* species (61 or more lateral line scales) by having 11-16 scales between the dorsal fin origin and the lateral line, the body and head without irregular brown to black speckles, total gill rakers 9-20, dorsal fin branched rays modally 8, and a wide distribution in the Dasht-e Lut, Hamun-e Jaz Murian, Hormuz, Kerman-Na’in, Kor River, Lake Maharlu, Persis (except Zohreh River basin) and Sirjan basins.

**Morphology.** This species is widely distributed and shows a wide range in morphology

and meristics. The body is rounded with a fairly uniform depth along the whole body, or relatively thick and deep. The body is deepest at the dorsal fin origin level or somewhat in advance of it, and there may be a nuchal hump in well-fed fish. The dorsal profile in front of the dorsal fin is smoothly to slightly convex and there is a predorsal ridge in some fish. Some fish may have an abrupt decline of the back immediately before the head. The caudal peduncle is compressed and moderately deep. The snout is rounded, protrudes somewhat, and a snout flap covers most of the upper lip but not completely. The mouth is subterminal, u-shaped in young and a shallow arc with a horny edge in adults, sometimes poorly-developed. Mouth shape is individually variable with fish of the same size having a different amount of arching. The upper lip is thick as is the lower lip at the corners. The rear of the eye is at the beginning of the anterior half of the head. The mouth, gill arch and rakers are finely spinulate. Barbels are thick but taper rapidly and extend back to the anterior half of the eye or to the posterior half. An extra anterior barbel is present rarely. The dorsal fin spine is weak with small to medium denticles which can be almost absent or extend along up to 70% or more of the spine, being more extensive in young. Denticles are aligned postero-ventrally when the spine is at right angles to the back and some may be horizontal at mid-spine or even all are horizontal. Heckel (1847b) distinguished his *Scaphiodon amir* and *S. niger* by the dorsal fin denticles being horizontal or perpendicular to the spine, not hooked downward as in related species. Berg (1949) did not attach any significance to this character. The dorsal fin margin is emarginate to almost straight. The dorsal fin origin is anterior to the pelvic fin origin level and the depressed fin does not reach back to the anal fin origin level. The caudal fin is moderately forked with rounded to pointed tips and lobes sometimes of unequal size, the lower being larger. The anal fin margin is straight to rounded and the fin extends almost to the caudal fin base or is relatively remote. The pelvic fin margin is rounded and the fin extends back to the anus or is remote from it. The pectoral fin margin is rounded and the fin does not extend back to the pelvic fin.

Dorsal fin with 3-7 unbranched and 7-10 branched rays, usually 8-9, anal fin unbranched rays 3 and branched rays 4-6, modally 5, pectoral fin branched rays 15-21, pelvic fin rays 7-10, lateral line scales 58-83, scales between dorsal fin origin and lateral line 9-16, modally 14-15, scales between anal fin origin and lateral line 7-10, modally 8-9, and caudal peduncle scales 23-28, modally 24 and 26. Scales are smaller on the belly and predorsally but are imbricate. There is a large pelvic axillary scale, up to four times as long as the scales above it. The dorsal and ventral margins of each scale are gently convex, the posterior margin is rounded and the anterior margin is centrally rounded with indentations above and below. The anterior corners are abrupt. Radii vary from very few anterior and posterior radii to very numerous and on all fields. The focus is almost central to subcentral anterior. The interradial space on the anterior part of the scale is wide and lepidonts are numerous. The anterior opening of the lateral line is small and the canal is short. Esmaeili *et al*. (2007) detailed scale structure of fish from southwest Iran identified as *C. damascina* using scanning electron microscopy. Teimori (2016) gave scanning electron microscopic details of scale structure as well as a macroscopic description. Total gill rakers number 9-20 (this wide range is for total rakers, see below), and lower limb rakers 9-15. The gill rakers reach the one below when appressed and are slightly hooked. The pharyngeal teeth are spatulate with the one next to the most anterior one in the major row rounded with a hollow crown. The most anterior tooth in the major row is small and can be absent, or not easily discerned. The gut has three loops. Total vertebrae number 41-46, modally 43-44. The syntypes of *Scaphiodon saadii*, NMW 51666, have 42(2)

43(8) or 44(1) vertebrae. The syntypes of *Scaphiodon amir*, NMW 46081, have 44(4), 45(1) and 46(1) total vertebrae. The syntypes of *Scaphiodon niger*, NMW 51654, 51655 and 51656, have 44(2) and 45(2) total vertebrae.

Alwan (2010) examined 72 fish and all had two posterior barbels except one fish that had two posterior and one anterior barbel. CMNFI 1979-0169 from a qanat near Mahan, Kerman had fish with two posterior barbels (7), two posterior barbels plus a left anterior barbel (2), two posterior barbels plus a right anterior barbel (5) and four barbels (22). The fish are small and the extra anterior barbels are often small nubs. Material with four barbels from this area are shown to be *C. saadii* by DNA evidence according to H. R. Esmaeili (pers. comm., 11 April 2016). A fish from CMNFI 1979-0207 has an anterior left barbel. Fish from CMNFI 1979-0209 has three fish with three barbels and four fish with four barbels out of 60 fish. A fish from CMNFI 1979-0113 has the left barbel forked.

Counts from Alwan (2010) and Alwan *et al*. (2016):- dorsal fin unbranched rays 3(1), 4(39), 5(24) or 6(7), dorsal fin branched rays 8(38) or 9(38), anal fin unbranched rays 3(74), anal fin branched rays 5(74), pectoral fin branched rays 17(5), 18(29), 19(23) or 20(14), pelvic fin branched rays 8(9), 9(53) or 10(13), lateral line scales, 61(1), 62(-), 63(2), 64(2), 65(3), 66(7), 67(5), 68(5), 69(4), 70(11), 71(4), 72(5), 73(3), 74(1), 75(1), 76(5), 77(2), 78(2) or 79(1), lower limb gill rakers 9(6), 10(21), 11(32), 12(7), 13(5), 14(1) or 15(1), total gill rakers 12(1), 13(9), 14(6) 15(1), 16(2) or 17(1), and total vertebrae 41(5), 42(16), 43(108), 44(78), 45(13) or 46(1). Jawad and Alwan (2020) gave total vertebrae as 42-44 in a limited sample for osteology. Pharyngeal teeth are 2,3,5-5,3,2(8) and similar to those of nominal *C. damascina*, being scalloped with a flat crown, the largest tooth in the major row rounded and the most anterior one there very small.

Meristic values are as follows and include some data from the syntypes of *Scaphiodon amir*, *S. niger* and *S. saadii*:- dorsal fin branched rays 7(16), 8(297), 9(96) or 10(2), anal fin branched rays 4(1), 5(390) or 6(1), pectoral fin branched rays 15(4), 16(12), 17(63), 18(176), 19(109), 20(38) or 21(1), pelvic fin branched rays 7(13), 8(357) or 9(35), lateral line scales 58(1), 59(5), 60(1), 61(12), 62(14), 63(19), 64(22), 65(20), 66(21), 67(29), 68(18), 69(22), 70(27), 71(20), 72(30), 73(24), 74(23), 75(15), 76(15), 77(9), 78(5), 79(10), 80(2), 81(1), 82(-) or 83(2), and total gill rakers 10(3), 11(21), 12(54), 13(75), 14(96), 15(80), 16(53), 17(15), 18(12), 19(2) or 20(1). Pharyngeal teeth 2,3,5-5,3,2(5), 2,3,4-5,3,2(2) or 2,3,4-4,3,2(1).

Mohammadi *et al*. (2018) described the morphology of the urohyal bone and the asteriscus otolith in fish from Kerman and found they could be used to discriminate not only species but also a geographically isolated population. Jawad and Alwan (2020) gave comparative details of the vertebral column and dorsal, anal and caudal fins in a study of the osteology of the *Capoeta damascina* species complex.

**Sexual dimorphism.** Large tubercles are found on the snout in front of the eye below the nostrils but not on the snout tip (e.g., in CMNFI 1979-0073, 86.6 mm standard length, 11 May 1976). Small tubercles in males cover the entire dorsal surface of the body from the snout to the caudal fin origin, on the body above and below the lateral line especially in the area above the anal fin, on the lateral line with one, two or three tubercles per scale but not on each scale, and on the anal fin branched rays 2-5 posteriorly and distally. In some cases, females may bear a small number of breeding tubercles on the sides of the snout (smaller than those in males). Even relatively small fish bear tubercles and have a well-developed anal papilla, e.g., CMNFI 1979-0211, 63.5 mm standard length. Tubercles are apparent in fish caught as early as 30 November 1976 (CMNFI 1979-0155) and 21 January 1977 (CMNFI 1979-0166), although

they are not well-developed and are absent from the snout.

The tip of the anal fin reaches to or beyond the vertical of the caudal fin base in females and to about two-thirds of the caudal peduncle in males. The outer anal fin margin is more convex in females.

**Colour.** This wide-ranging species shows various colour patterns, varying with habitat, locality, age, condition and maturity. The back, head and flanks sides of fish from the Kor River basin are golden-yellow, darker dorsally and lighter below the lateral line. The dorsal, anal and caudal fins are light golden, the pectoral and pelvic fins golden-yellow. The upper half of the body of fish from other river drainages is light golden or silvery-grey and the lower half white, with or without a grey tinge. Fins are white-yellowish or dusty grey. A few dark blotches (> 4 mm) are present on the body of some adult, subadult and juvenile specimens. A very large, dark blotch was found on the upper and middle flank just behind the dorsal fin on one fish (Esmaeili *et al*., 2015). Large spots and blotches appear irregularly positioned on the flank from quite small (less than pupil size) to 3-4 times larger than the eye. The number, size and position of these spots differ on each flank. Many fish do not have these large spots and blotches. In addition, juvenile specimens have a diffuse lateral band along the sides and small diffuse black spots or blotches above the lateral line. Small black spots may extend onto the lower flank. The small spots are concentrated into a caudal spot in some young fish. The peritoneum is brown to black.

Preserved fish have the back, head and sides grey dorsally and beige or yellow ventrally. Fins are beige or dusty grey. A dark lateral band (in juveniles), spots (in juveniles) and blotches are evident (Alwan, 2010).

Some fish may be very black with only the underside of the head and belly yellowish-white (specimens described by Heckel (1847b) as *Scaphiodon niger*; however, since these fish "decompose quickly in the commonly used ethyl alcohol concentrations", they may have been poorly preserved and the black colouration resulted from partial decomposition).

**Size.** Attains 31.6 cm total length (Paighambari *et al*., 2020).

**Distribution.** This species is found in many springs and qanats not all listed immediately below (see **Sources**) and other water bodies in the Dasht-e Lut, Hamun-e Jaz Murian, Hormuz, Kerman-Na'in, Kor River, Lake Maharlu, Persis and Sirjan basins. In the Dasht-e Lut basin from the Ab-Barik, Debegri, Fahraj, Ghoyeh, Gishtigan, Khamrotag, Koli and Tahrud rivers; in the Hamun-e Jaz Murian basin in the Baft, Bampur, Delfard, Halil, Kahiri, Kahnai, Kharan, Rabor, Rudbar, Saiedmorteza, Shur and Soltani rivers; in the Hormuz basin from the Galehgah, Jalabi, Kul, Mehran, Rudan and Shur rivers, and the Golabi Spring; in the Kerman-Na'in basin generally in springs and qanats such as Jowzam Spring; in the Kor River basin from the Kor, Pulvar and Shadkam rivers, Ghadamgah Spring-Stream system, Gomban, Malousjan and Sarab springs, Kaftar Lake and the Dorudzan Dam; in the Lake Maharlu basin from the Khoshk River, Pirbanoo Spring and Sa`di's Tomb; in the Persis basin from the Abarak, Dalaki, Dasht-e Palang, Helleh, Jereh, Kergeh, Kohmarreh Sorkhi, Mond, Pol-e Nilo (= Pol-e Nalu), Qarah Aqaj, Qasook, Rudbal (= Rudbar), Shapur, Shur, Zakheh and Zanjiran rivers, Dadina Spring, Haft Barm lakes, Lake Parishan, Chehel Cheshmeh and Dasht-e Arjan Wetland; and in the Sirjan basin generally in springs and qanats and the Chary, Hosseinabad-souch, Lalehzar, Qudari and Tangohihe rivers (Gh. Izadpanahi, pers. comm., 1995; M. Rabbaniha, pers. comm., 1995; Abdoli, 2000; Barzegar and Jalali, 2002; Alwan, 2010; Ebrahimi, 2010; Teimori *et al*., 2010; Levin *et al*., 2012; Pazira *et al*., 2012, 2016; Zareian *et al*., 2012, 2016; Rahimi and Tabiee, 2013; Esmaeili *et al*., 2015; Hashemzadeh

Segherloo, 2015; Jouladeh-Roudbar *et al*., 2015; Sayari and Rahmani, 2015; Alwan *et al*., 2016, 2016; Ghanavi *et al*., 2016; Hosseini *et al*., 2016; Teimori, 2016; Gholamifard and Kafaei, 2017; Zamanpoore and Yaripour, 2017; Mohammadi *et al*., 2018; Paighambari *et al*., 2020; Gholamifard and Kafaei, 2021).

Askari Hesni *et al*. (2014) examined 39 qanats and springs in the Kerman-Na'in basin around Zarand and Kouhbanan, Kerman Province, identifying the fish as *C. damascina*. Zarand had fish present at 13 of 21 sites and Kouhbanan at eight of 18 sites.

**Zoogeography.** See under the genus *Capoeta* above. *C. saadii* haplotypes showed differences between populations, a consequence of their isolation in separate basins and restricted gene flow. Zareian *et al*. (2018) placed this species in the *C. damascina* species group of *Capoeta* where it separated 1.54 MYA.

**Habitat.** This species is found in rivers, streams, backwaters, lakes, dams, lagoons, ponds, marshes, springs, qanats and brackish environments. Large fish cornered in small streams will jump over seine nets! Parsi *et al*. (2014) found this species (identified as *C. damascina*) in qanats and springs in the Kouhbanan region of northern Kerman Province at a temperature range of 17.0-25.6°C, pH 6.84-7.93, dissolved oxygen 5.21-7.8 mg/l and conductivity 546-7,350 µs/cm. The largest numbers of fish were found in environments having neutral pH, high temperature and low conductivity. Zareian and Esmaeili (2017) reported this species from medium flowing rivers with muddy bottoms. This species is widely distributed in a variety of habitats in southwestern Iran and this is reflected in habitat data. Collection data included a temperature range of 8-26ºC, pH 6.0-7.0, conductivity 0.08-4.3 mS, river width 22 cm to 40 m, still to fast current, depth 15 cm to 4.0+ m, clear and colourless, cloudy or muddy water, mud, sand, gravel, pebble, stone, boulders, bedrock or concrete bottoms, encrusting, submergent *Ceratophyllum*, *Sagittaria*, filamentous algae and gelatinous brown masses, emergent reeds and rushes, foliose and floating vegetation, and a grassy or forested shore.

Habitat of *Capoeta saadii* (and *Cyprinion watsoni*), CMNFI 1979-0309,
Kerman, Fahraj River at Azizabad, 30 November 1977, Brian W. Coad.

Habitat of *Capoeta saadii*, Fars, Rudbal River
(Rudbal Darab …., in Farsi, CC BY-SA 4.0, Aboalfaz1524).

**Age and growth.** Pazira *et al*. (2012) examined fish identified as *C. capeota intermedia* (*sic*, either *C. saadii* or *C. mandica*) from the Dalaki, Shapur and Helleh rivers and found a maximum age of 6 years with two-year-old fish the most common. Fish reached 250 mm and 143 g. Males outnumbered females. Bibak *et al*. (2013b) gave a length-weight relationship for 169 fish, 2.1-22.4 cm total length, identified as *C. capoeta intermedia* (see above for possible identities) from the Dalaki River as $W = 0.011L^{3.123}$ and for 223 or 224 fish (count differs in text; 1.8-21.0 cm total length) from the Shapur River as $W = 0.011L^{3.148}$, both showing allometry and no significant difference between the rivers. Sedaghat *et al*. (2013) gave a length-weight relationship for fish identified as *C. capoeta intermedia* (see above for possible identities) from the Dalaki River. Thirty females, 11.0-21.5 cm total length, had negative allometry and $W = 0.05L^{2.87}$ and 40 males, 7.6-12.9 cm total length, had positive allometry and $W = 0.07L^{3.79}$. Sexes combined had the formula $W = 0.06L^{3.21}$. Kheyrandish *et al*. (2014) found 5 age classes, to $4^+$ years, in fish identified as *C. damascina* and 7.2-24.4 cm long from the Dalaki River. The most frequent size classes were 11-13 cm for males and 15-17 cm for females. Condition factor ranged from 0.68 to 1.36 and females dominated over males (1:1.55). Sayari and Rahmani (2015) found 142 fish identified as *C. damascina* from the Rudbal (= Rudbar) River in Fars had summer, autumn and winter average total lengths of 155.88, 130.31 and 103.21 mm, average total weights 46.61, 36.21 and 14.11 g respectively, and length-weight relationships $W = -10.522+2.827L$, $-10.912+2.899L$ and $-13.18+3.381L$ respectively. Sayyari and Hossein (2016) also examined 183 fish identified as *C. damascina*, 55.35-245.0 mm, from the Roudbal (= Rudbar) River in Fars and found five age classes ($1^+$ to $5^+$ years), one-year-old fish were the highest frequency for both sexes, the sex ratio was 1:1.28 in favour of females, the length-weight relationships were $W = 0.00002L^{2.84}$ for males and $W = 0.00001L^{2.94}$ for females, and the von Bertalanffy growth equation was estimated as $L_t =$

17.061(1-$e^{-0.651(t+0.108)}$) for males and $L_t$ = 34.94 (1-$e^{-0.19 (t+0.05)}$) for females, and consequently the infinity length in females was remarkably more than males. The condition factor and relative condition factor of different ages were higher in males and females respectively, and these increased with age in both sexes. The natural mortality rate was calculated as 1.38 and 0.273 in males and females, respectively. Zareian *et al*. (2018a) gave a *b* value of 2.798 for 29 fish, 10.3-17.5 cm total length. Paighambari *et al*. (2020) gave a *b* value of 2.92 for 21 fish (18.4-31.6 cm total length) identified as *C. damascina* from the Dorudzan Dam, Fars.

**Food.** Sayyari and Rahmani (2016) examined fish identified as *C. damascina* from the Roudbal (= Rudbar) River in Fars and found the relative length of gut revealed this fish as herbivorous and the fullness index in both sexes at different ages showed that its feeding status was fairly poor.

**Reproduction.** Hosseini and Sotoudeh (2016) and Hosseini *et al*. (2016) examined 330 fish from the Shapur River identified as *C. c. intermedia* (*sic,* either *C. saadii* or *C. mandica*) and found a female:male sex ratio of 1:1.66, reproduction occurred from February to June based on gonadosomatic indices, egg diameter was 2112.9 μm in stage 5, and absolute fecundity was 105-8,134 eggs (mean 2,252.6 eggs). Sayyari and Hossein (2016) examined fish identified as *C. damascina* from the Roudbal (= Rudbar) River in Fars and found absolute fecundity and relative fecundity were 4,392 eggs and 55.39 eggs/g, respectively.

**Parasites and predators.** Dollfus (1970) described a new cestode *Coelobothrium monodi* from fish identified as *Varicorhinus damascinus umbla* at Nasratabad, possibly from the Dasht-e Lut basin. Molnár and Jalali (1992) recorded the monogenean *Dactylogyrus lenkorani* in the Kor River drainage of Fars from fish identified as *C. capoeta*. González-Solís *et al*. (1997) reported the nematodes *Rhabdochona denudata* and *Rhabdochona fortunatowi* from this species identified as *C. damascina* in the Mond River, Fars. O. M. Amin (pers. comm., 1998) identified the acanthocephalan *Acanthocephalorhynchoides cholodkowskyi* from specimens collected in the Mond River west of Shiraz, Fars. Barzegar and Jalali (2002) reported a parasite in this species identified as *C. damascina* from Kaftar Lake as *Dactylogyrus lenkorani*. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Lernaea cyprinacea* on fish identified as *C. damascina* in the Kaftar Lake. Nazari Chamak *et al*. (2010) found the following myxozoan parasites in the genus *Myxobolus*: *buckei, cristatus, karelicus, musajevi, samgoricus, suturalis* and *varicorhini* in fish from the Halil River, Kerman identified as *C. damascina*. Pazooki *et al*. (2012) found the nematodes *Contracaecum micropapillatum, Hepaticola petruschewkii*, *Rhabdochona denudata* and *R. macrostoma* in fish identified as *C. damascina* from Kerman (Abshur, Halil, Jafarabad and Konarooleh rivers). Gholami *et al*. (2014) found this species, identified as *C. damascina*, was a new host for the nematodes *Contracaecum* sp. and *Capillaria* sp. in the Gomban Spring-Stream system of the Kor River basin. Both these parasites are zoonotics, capable of infecting humans. Yazdanpanah Goharrizi (2014) recorded *Lernaea* and *Ligula* from fish identified as *C. damascina* in the Baft River, Kerman. Sayyadzadeh *et al*. (2016) found the anchor worm *Lernaea cyprinacea* in fish from the Kor River basin, presumably from the introduced species *Carassius auratus* and/or *Cyprinus carpio*.

Yazdanpanah Goharrizy (2007) maintained fish identified as *C. damascina* from the Baft River, Kerman in aquaria at various temperatures. Fin haemorrhages and corrosion and unusual swimming movements were found in 80% of fish at 20-30°C or higher, falling to 40% of fish at 10-20°C and only 1% at below 10°C. The bacterium *Aeromonas hydrophila*, a major fish pathogen, was isolated from the kidneys and fins. Yazdanpanah Goharrizi *et al*. (2015)

studied the effect of temperature stress on clinical signs and mortality caused by *Aeromonas hydrophila*, the pathogen responsible for economic loss in aquaculture. Fish from Baft, Kerman were injected with the bacterium intraperitoneally and most clinical signs and mortality occurred at 20-30°C, with 40% at 10-20°C and 1% below 10°C. Capture, handling and transport of fish should be carried out at low temperatures.

The presence of pelicans on the Kor River may indicate feeding on this species (see photograph in description of this basin above).

**Economic importance.** This species has been of no major economic importance in Iran although attempts have been made to introduce it to culture systems in Fars (Sayari and Rahmani (2015) as *C. damascina*). Heckel (1847b) reported that this species was “greatly appreciated as food fish by the local people” in the Kor River basin, Fars (as his *Scaphiodon amir*). Samaee and Patzner (2011) mentioned that it is fished recreationally in Iran and consumed as *C. damascina*. This species has been angled in a Haft Barm lake by F. Hosseinie (October 1978, CMNFI 1979-0502).

**Experimental studies.** Askary Sary *et al*. (2013) found levels of lead and cadmium in the liver of fish from the Shapur River were lower than international standards prohibiting consumption.

**Conservation.** Jouladeh Roudbar *et al*. (2020) listed it as of Least Concern as it is widespread, abundant to very abundant and there is no known widespread threat.

**Sources.** Type material:- *Scaphiodon saadii* (NMW 51666, 55900), *Scaphiodon amir* (NMW 46081) and *Scaphiodon niger* (NMW 51654, 51655, 51656).

Iranian material:- CMNFI 1977-0510A, 4, 27.9-37.7 mm standard length, Fars, qanat stream at Naqsh-e Rostam (29º59'30"N, 52º54'E); CMNFI 1979-0020, 5 (in part), 46.0-50.2 mm standard length, Fars, Mond River outside Kavar (29º11'N, 52º41'E); CMNFI 1979-0021, 97, 13.9-45.3 mm standard length, Iran, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0022, 94, 25.1-39.3 mm standard length, Iran, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0024, 376, 12.4-41.4, mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0026, 15, 24.4-48.7, mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0027, 1, 71.9 mm standard length, Fars, Chehel Cheshmeh (ca. 29º43'N, ca. 52º04'E); CMNFI 1979-0028, 67 of 85, 23.1-37.1 mm standard length, Fars, Zarqan, Kor River drainage (no other locality data); CMNFI 1979-0036, 2, 83.9-118.3 mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0043, 1, 74.8 mm standard length, Fars, qanat behind Sarvestan (29º16'N, 53º14'E); CMNFI 1979-0044, 5, 18.5-38.4 mm standard length, Fars, qanat at Mian Jangal (29º09'N, 53º27'E); CMNFI 1979-0053, 6, 47.3-79.5 mm standard length, Fars, Shur River tributary (ca. 28-29º58-03'N, ca. 52º34-35'E); CMNFI 1979-0054, 16, 35.8-127.9 mm standard length, Fars, Shur River tributary (ca. 28-29º58-03'N, ca. 52º34-35'E); CMNFI 1979-0058, 6, 75.6-115.3 mm standard length, Fars, jube over Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0061, 4 of 6, 52.2-57.4 mm standard length, Fars, stream tributary to Pulvar River (30º04'N, 53º01'E); CMNFI 1979-0063, 2, 201.0-206.7 mm standard length, Fars, Sa`di's Tomb, Shiraz (29º37'N, 52º35'E); CMNFI 1979-0067, 27, 16.4-68.0 mm standard length, Fars, qanat at Zarqan (ca. 29º46'N, ca. 52º43'E); CMNFI 1979-0073, 6, 28.9-86.6 mm standard length, Fars, Mond River beyond Chehel Chashhmeh (ca. 29º42'30"N, ca. 52º01'30"E); CMNFI 1979-0074, 43, 24.4-72.9 mm standard length, Fars, Mond River backwater (29º41'N, 52º06'E; CMNFI 1979-0075, 9 (in part), 35.8-80.4 mm standard length, Fars, Mond River at Pol-e Kavar (29º11'N, 52º41'E); CMNFI 1979-0079, 2, 120.7-149.9 mm standard length, Fars,

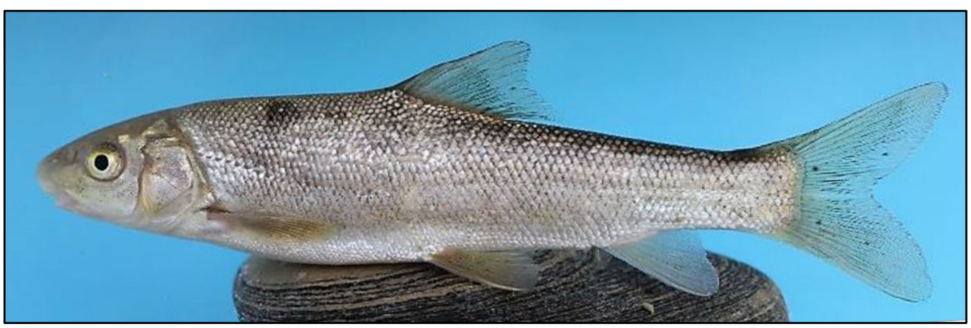
Mond River 5 km above Band-e Bahman (ca. 29º12'N, ca. 52º38'E); CMNFI 1979-0085, 5, 57.0-86.7 mm standard length, Fars, Hosseinabad (no other locality data); CMNFI 1979-0109, 1, 103.4 mm standard length, Fars, Mond River at Shahr-e Khafr (28º56'N, 53º14'E); CMNFI 1979-0111, 1, 54.0 mm standard length, Fars, stream on Shiraz-Bushehr road (29º37'30"N, 52º21'E); CMNFI 1979-0113, 3, 68.9-195.3 mm standard length, Fars, Sa`di's Tomb (29º37'N, 52º35'E); CMNFI 1979-0114, 1, 30.7 mm standard length, Fars, Mond River at road bridge (29º41'N, 52º06'E); CMNFI 1979-0115, 4, 154.4-172.6 mm standard length, Fars, Sa`di's Tomb (29º37'N, 52º35'E); CMNFI 1979-0128, 16, 34.6-108.6 mm standard length, Fars, Shur River between Atashkadeh and Firuzabad (28º51'N, 52º31'E); CMNFI 1979-0130, 5, 44.4-93.3 mm standard length, Fars, stream tributary to Shur River 4 km west of Firuzabad (28º51'N, 52º32'E); CMNFI 1979-0131, 59, 25.5-140.0 mm standard length, Fars, Abarak River (28º38'N, 52º49'E); CMNFI 1979-0132, 23, 51.1-74.4 mm standard length, Fars, Shur River 54 km from Firuzabad (28º35'N, 52º58'E); CMNFI 1979-0155, 7, 36.2-80.5 mm standard length, Fars, spring at Gavanoo (28º47'N, 54º22'E); CMNFI 1979-0157, 17, 35.8-56.5 mm standard length, Fars, qanat stream at Hadiabad (28º52'N, 54º13'E); CMNFI 1979-0158, 31, 33.8-54.1 mm standard length, Fars, qanat jube over Qasook River (28º54'N, 53º53'30"E); CMNFI 1979-0159, 91, 23.1-167.3 mm standard length, Fars, qanat at Qaziabad (ca. 28º54'N, ca. 53º43'E); CMNFI 1979-0160, 4, 66.3-138.4 mm standard length, Fars, spring at Arteshkhadeh Pomp (29º09'N, 53º37'E); CMNFI 1979-0161, 29, 33.2-88.3 mm standard length, Fars, qanat on Neyriz to Shiraz road (29º10'30"N, 53º41'E); CMNFI 1979-0162, 9, 14.2-88.3 mm standard length, Fars, qanat behind Sarvestan (29º16'30"N, 53º14'E); CMNFI 1979-0163, 2, 35.3-73.8 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0164, 1, 49.4 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0165, 7, 30.0-96.6 mm standard length, Kerman, qanat at Ahmadabad (30º32'N, 55º38'E); CMNFI 1979-0166, 68, 37.1-123.1 mm standard length, Kerman, qanat at Hassanabad-e Nuq (30º43'N, 55º50'E); CMNFI 1979-0168, 3, 40.9-70.2 mm standard length, Kerman, qanat at Shahabad (29º07'N, 58º16'E); CMNFI 1979-0169, 36, 27.4-55.0 mm standard length, Kerman, qanat 10 km from Mahan (30º08'30"N, 57º17'E); CMNFI 1979-0170, 15, 17.9-56.2 mm standard length, Kerman, qanat at Baghin (30º12'N, 56º48'E); CMNFI 1979-0171, 81, 12.6-23.4 mm standard length, Kerman, qanat at Bardesir (29º56'N, 56º34'E); CMNFI 1979-0192, 6, 37.6-42.1 mm standard length, Fars, qanat 2 km east of Rostaq (28º26'30"N, 55º04'E); CMNFI 1979-0195, 2, 53.7-56.5 mm standard length, Fars, jube on road to Fasa (ca. 28º54'N, ca. 53º53'30"E); CMNFI 1979-0199, 6, 70.8-102.1 mm standard length, Fars, qanat 18 km from Jahrom (ca. 28º23-25'N, ca. 53º31-40'E); CMNFI 1979-0203, 10, 25.4-54.6 mm standard length, Fars, qanat at Dudej (29º33'N, 52º59'E); CMNFI 1979-0204, 6, 32.7-51.9 mm standard length, Fars, qanat on road to Kharameh (29º33'N, 52º59'E); CMNFI 1979-0205, 12, 45.9-200.5 mm standard length, Fars, jube at Runiz-e Pa'in (29º12'N, 53º42'E); CMNFI 1979-0206, 3, 32.9-39.9 mm standard length, Fars, qanat near Runiz-e Pa'in (29º12'N, 53º40'E); CMNFI 1979-0207, 12, 24.2-83.7 mm standard length, Fars, jube 22 km from Neyriz (29º16'N, 54º28'E); CMNFI 1979-0208, 6, 39.9-130.4 mm standard length, Fars, qanat 47 km from Neyriz (ca. 29º11'N, ca. 54º40'E); CMNFI 1979-0209, 60, 43.6-138.9 mm standard length, Kerman, qanat at Kuch Kuluh (29º25'N, 56º03'E); CMNFI 1979-0211, 66, 33.2-94.3 mm standard length, Kerman, river on road to Baft (29º19'N, 56º12'E); CMNFI 1979-0212, 73, 26.0-99.1 mm standard length, Kerman, qanat on road to Baft (29º14'N, 56º17'E); CMNFI 1979-0213, 5, 51.4-60.2 mm standard length, Kerman, stream in Kharan River drainage (29º15'N, 56º25'E); CMNFI 1979-0214, 354, 27.1-73.4 mm standard length,

Kerman, qanat pool on road to Baft (ca. 29º15'N, ca. 56º28'E); CMNFI 1979-0215, 11, 35.5-125.9 mm standard length, Kerman, Kharan River drainage (29º14'N, 56º37'E); CMNFI 1979-0216, 17, 51.1-65.8 mm standard length, Kerman, qanat 9 km from Baft (ca. 29º13'N, ca. 56º42'E); CMNFI 1979-0217, 15, 39.7-125.9 mm standard length, Kerman, Kharan River drainage (ca. 28º59'30"N, ca. 56º51'30"E); CMNFI 1979-0221, 1, 39.0 mm standard length, Kerman, river in Halil River drainage (28º51'N, 57º52'E); CMNFI 1979-0241, 6, 57.1-90.7 mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0306, 11, 17.6-46.1 mm standard length, Kerman, qanat on road to Baft (29º13'N, 54º33'E); CMNFI 1979-0307, 5, 50.9-73.4 mm standard length, Kerman, river at Sartal 6 km from Baft (ca. 29º17'N, ca. 56º38'E); CMNFI 1979-0308, 47, 20.5-246.9 mm standard length, Kerman, river 44 km from Baft (29º02'N, 56º50'E); CMNFI 1979-0309, 1, 261.1 mm standard length, Kerman, Fahraj River at Azizabad (28º57'N, 58º42'E); CMNFI 1979-0315, 2, 53.5-65.5 mm standard length, Baluchestan, Bampur River 2 km north of Karvandar (27º51'N, 60º46'E); CMNFI 1979-0337, 22, 32.2-154.2 mm standard length, Baluchestan, stream near Kanowak (ca. 28º40'N, ca. 60º48'E); CMNFI 1979-0341, 14, 27.2-75.9 mm standard length, Kerman, Tahrud west of Bam (29º23'N, 57º52'E); CMNFI 1979-0419, 1, 62.2 mm standard length, Fars, stream 7 km from Rostaq (28º29'N, 55º01'E); CMNFI 1979-0425, 6 of 12, 139.6-370.7 mm standard length, Fars, Haft Barm-e Kudian (29º49'N, 52º02'E); CMNFI 1979-0497, 3, 49.8-113.0 mm standard length, Fars, Mond River at Band-e Bahman (29º11'N, 52º40'E); CMNFI 1979-0499, 1, 192.1 mm standard length, Fars, irrigation ditch 32 km from Kor River bridge (30º04'30"N, 52º36'E); CMNFI 1979-0501, 7, 34.1-110.9 mm standard length, Fars, Mond River at Kavar (29º11'N, 52º41'E); CMNFI 1979-0502, 2, 289.4-390.4 mm standard length, Fars, Haft Barm-e Kudian (29º49'N, 52º02'E); CMNFI 1979-0503, 4, 153.3-185.3 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0689, 3, 186.3-245.8, Fars, Shiraz Bazar (no other locality data); CMNFI 2007-0030, 14, 53.4-130.4 mm standard length, Baluchestan, stream near Eskelabad (28º35'N, 60º48'E); CMNFI 2007-0031, 1, 66.8 mm standard length, Baluchestan, headwaters of Bampur River (27º51'N, 60º46'E); CMNFI 2007-0037, 10, 39.5-112.5 mm standard length, Kerman, Hosseinabad and Gamatabad qanats at Bam (29º06'N, 58º21'E); CMNFI 2007-0038, 2, 126.6-150.0 mm standard length, Kerman, Mehtiabad qanat (29º06'N, 58º21'E); CMNFI 2007-0039, 1, 55.4 mm standard length, Kerman, Tahrud River (ca. 29º23'N, ca. 57º53'E); CMNFI 2007-0040, 7, 84.2-119.9 mm standard length, Kerman, Qahariz qanat at Jupar (30º04'N, 57º08'E); CMNFI 2007-0041, 6, 64.9-91.7 mm standard length, Kerman, qanat at Baghin (30º12'N, 56º48'E); CMNFI 2007-0042, 7, 62.3-106.3 mm standard length, Kerman, qanat at Negar (29º52'N, 56º50'E); CMNFI 2007-0043, 8, 47.9-61.4 mm standard length, Kerman, qanat at Emamzadeh Sultan (ca. 29º40'N, ca. 56º45'E); CMNFI 2007-0044, 6, 55.5-96.3 mm standard length, Kerman, Qal'eh-ye Askar stream (ca. 29º28'N, ca. 56º38'E); CMNFI 2007-0045, 17, 25.0-78.7 mm standard length, Kerman, Kharan River drainage at Baft (29º14'N, 56º38'E); CMNFI 2007-0047, 11, 39.8-123.2 mm standard length, Kerman, qanat at Hoshun (29º14'N, 56º19'E); CMNFI 2007-0048, 11, 59.2-127.5 mm standard length, Kerman, qanat at Hasanabad (ca. 28º50'N, ca. 55º50'E); CMNFI 2007-0049, 1, 38.3 mm standard length, Hormozgan, upper Kul River basin at Hajjiabad (ca. 28º19'N, ca. 55º55'E); CMNFI 2007-0065, 2, 185.2-185.9 mm standard length, Fars, Barm-e Dalak (ca. 29º35'N, ca. 52º38'E); CMNFI 2007-0066, 1, 142.6 mm standard length, Fars, Sa`di's Tomb, Shiraz (29º37'N, 52º35'E); CMNFI 2007-0068, 5, 59.0-89.6 mm standard length, Fars, qanat 4 km south of Abarqu (ca. 31º07'N, ca. 53º14'E); CMNFI 2007-0069, 1, 78.9 mm standard length, Yazd, qanat at Zarej (ca. 31º58'N, ca. 54º17'E);

CMNFI 2007-0070, 2, 75.6-160.8 mm standard length, Yazd, qanat at Ardakan, (32º19'N, 53º59'E); CMNFI 2008-0248, 3, 153.4-168.0 mm standard length, Fars, Qarah Aqaj River near Firuzabad (29º31'03"N, 52º15'E); CMNFI 2008-0254, 3, 76.9-99.3 mm standard length, Fars, Qarah Aqaj River (29º31'03"N, 52º15'E); CMNFI 2008-0255, 2, 135.9-137.6 mm standard length, Fars, Kor River (30º00'N, 52º44'8"E); CMNFI 2008-0257, 4, 95.4-174.2 mm standard length, Fars, Marghan River near Sepidan (30º30'14"N, 51º53'19"E); CMNFI 2008-0258, 4, 109.8-133.5 mm standard length, Fars, Khirabad Stream near Fasa (28º56'18"N, 53º38'54"E); CMNFI 2008-0259, 5, 91.6-175.7 mm standard length, Fars, Atashkadeh Stream near Fasa (28º56'18"N, 53º38'54"E); CMNFI 2008-0261, 5, 72.6-111.8 mm standard length, Fars, Shesh Pir River near Sepidan (29º58'19"N, 52º24'04"E); CMNFI 2008-0263, 3, 109.1-165.9 mm standard length, Fars, Qarah Aqaj River (29º31'03"N, 52º15'E); CMNFI 2008-0264, 5, 95.3-139.5 mm standard length, Fars, qanat at Sar Gar Borazjan (28º45'11"N, 52º32'55"E); CMNFI 2008-0265, 5, 100.7-171.0 mm standard length, Fars, qanat at Banyan (28º19'59"N, 55º11'06"E); CMNFI 2008-0266, 4, 63.6-82.5 mm standard length, Fars, qanat at Kherak (29º42'36"N, 52º08'54"E); CMNFI 2008-0280, 1, 101.2 mm standard length, Fars, Ghadamgah Stream (30º15'12"N, 52º25'32"E); CMNFI 2008-0281, 1, 104.9 mm standard length, Fars, Zanjiran Stream, Firuzabad (29º04'23"N, 52º39'11"E); CMNFI 2008-0282, 1, 120.2 mm standard length, Fars, stream at Kazerun (29º17'01"N, 51º50'25"E); CMNFI 2008-0284, 1, 80.9 mm standard length, Fars, Akbarabad (28º57'59"N, 53º35'48"E); CMNFI 2008-0285, 1, 144.4 mm standard length, Fars, Kohmarreh Sorkhi River (29º23'36"N, 52º09'28"E); CMNFI 2008-0286, 1, 125.3 mm standard length, Fars, Shesh Pir River (30º15'22"N, 52º03'05"E); CMNFI 2008-0287, 2, 58.4-153.8 mm standard length, Fars, Dashte-e Arjan Wetland (29º39'23"N, 51º52'17"E); USNM 205933, 5, 97.5-142.4 mm standard length, Baluchestan, Karvandar Creek (no other locality data).

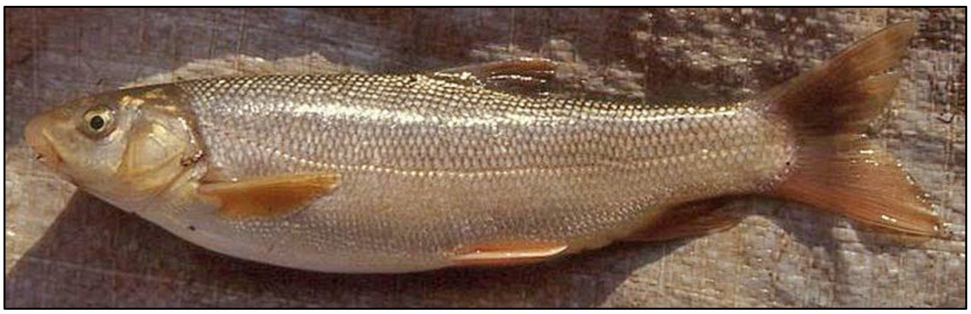
## ***Capoeta shajariani***

Jouladeh-Roudbar, Eagderi, Murillo-Ramos, Ghanavi and Doadrio, 2017

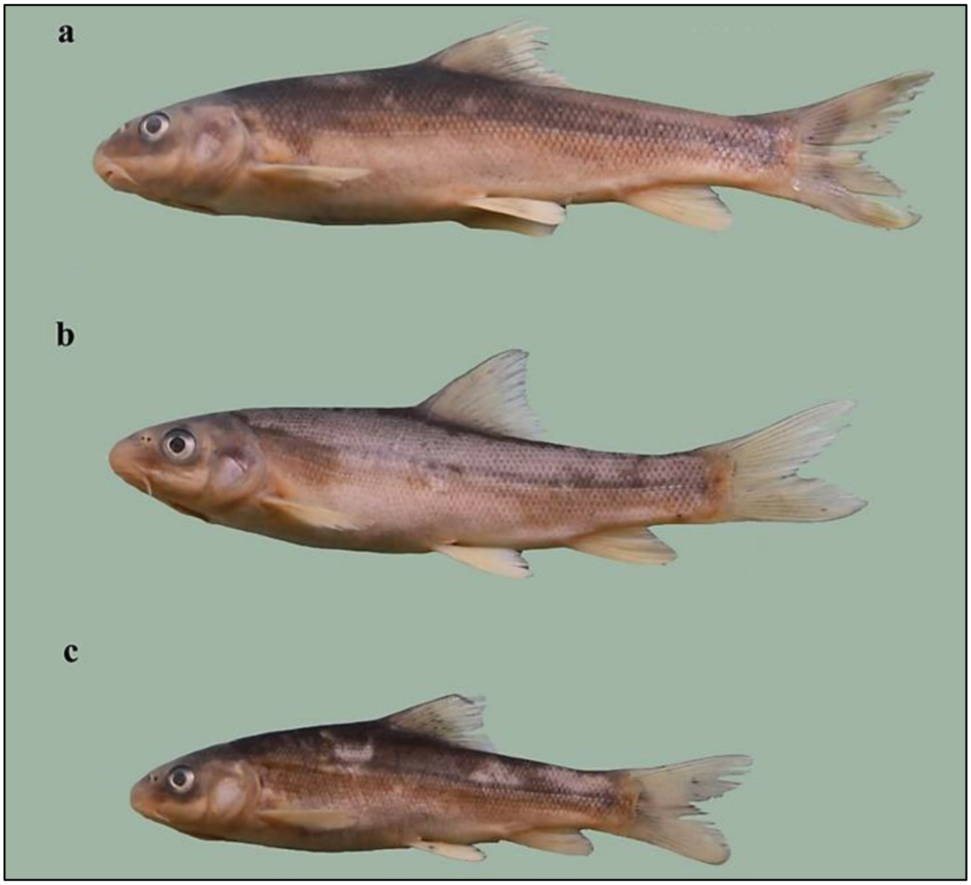


*Capoeta shajariani*, ZM-CBSU Z800-808,
Kermanshah, Gamasiab River at Darakeh (= Derkeh), Hamid Reza Esmaeili.

*Capoeta shajariani*, 149.0 mm standard length, IMNRF-UT-1106 49,
Hamedan, Gamasiab River at Saad-e Vaghas Village,
after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.



*Capoeta cf. shajariani*, CMNFI 2008-0175, Lorestan, Kahman River at
Dow Ab-e Aleshtar, 3 December 2000, Brian W. Coad.



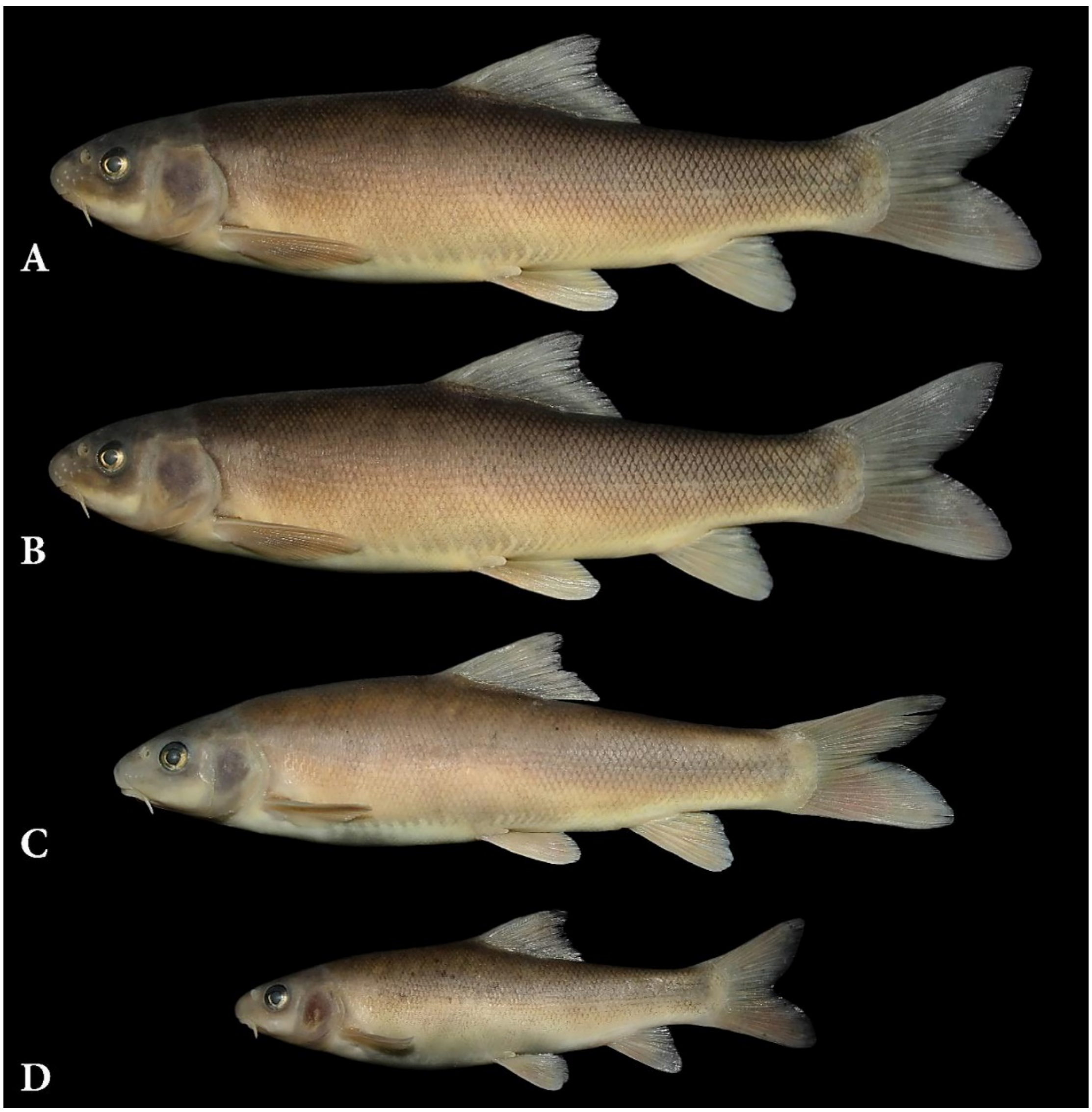

*Capoeta shajariani*, Kermanshah, Gamasiab River at Darakeh (= Derkeh), a) 102.0 mm standard length, ZM-CBSU Z800, b) 95.0 mm standard length, ZM-CBSU Z801, c) 73.0 mm standard length, ZM-CBSU Z802, Hamid Reza Esmaeili.

**Common names.** Siyah mahi Shajarian.

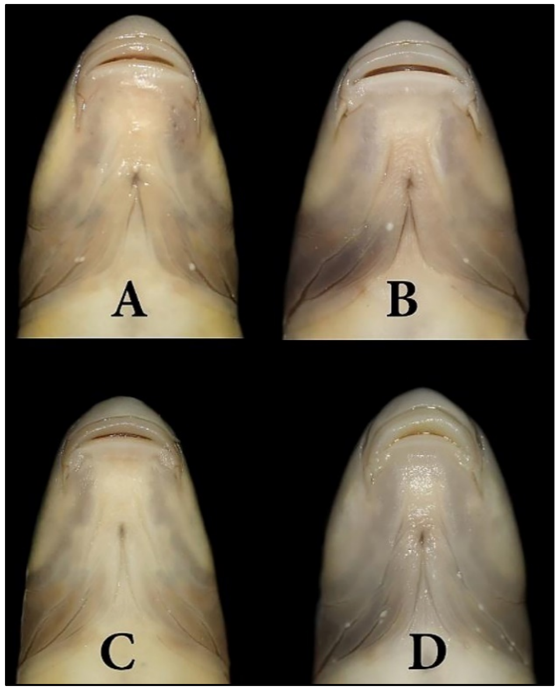
[Gamasiab scraper, Shajarian scraper].

**Systematics.** The holotype is under IMNRF-UT-1107 21 (Ichthyological Museum of Natural Resources Faculty, University of Tehran, Karaj), 162.4 mm standard length, Hamedan, Gamasiab River near Doab Village, Tigris River drainage (34°22'13"N 47°54'26"E), and paratypes are under IMNRF-UT-1107, 10, 93.5-173.0 mm standard length, same data as holotype and IMNRF-UT-1106, 10, 93.9- 203.2 mm standard length, Hamedan, Gamasiab River at Saad-e Vaghas Village, Tigris River drainage (34°16'54"N 48°14'29"E). The species is named to honor of Mohammad-Reza Shajarian, an acclaimed Iranian classical singer, composer and master of Persian traditional music.

*Capoeta shajariani*, holotype, IMNRF-UT-1107 21, after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.




*Capoeta shajariani*, paratypes, A, 169 mm standard length, IMNRF-UT-1107 26,
B, 160 mm standard length, IMNRF-UT-1107 24, C, 142 mm standard length, IMNRF-UT-1107 27,
D, 93 mm standard length, IMNRF-UT-1107 29, after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.




*Capoeta shajariani*, holotype, A, 162 mm
standard length, IMNRF-UT-1107 21,
paratypes, B, C, D (as B, A, C above),
after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

**Key characters.** This species is distinguished from other small-scaled *Capoeta* species (61 or more lateral line scales) by having 13-15 scales between the dorsal fin origin and the lateral line, the body and head without irregular brown to black speckles, total gill rakers 14-21, dorsal fin branched rays modally 9, and a distribution in the Karkheh River basin of the Tigris River basin.

**Morphology.** The body is relatively high and compressed laterally. The dorsal profile of the head is slightly convex with a less arched ventral profile. The predorsal body profile is convex with an elevated keel in front of the dorsal fin origin. The greatest body depth is at the level of the dorsal fin origin, or in advance in pregnant or fatty fish. The caudal peduncle is compressed and moderately deep. The snout is rounded, protruding, blunt or tapering and arched in ventral view. There may be a groove across the snout. The mouth is arched in males, straight in females and u-shaped in young. The rostral cap is well-developed and partly covers the upper lip. The upper and lower lips are adnate to the jaws, and the lower jaw is covered with a keratinized edge. The maxillary barbel mostly does not reach back to the pupil and is thin. The rear of the eye is at the beginning of the anterior half of the head. The dorsal fin margin is concave and the dorsal origin is anterior to the level of the pelvic fin origin. The depressed dorsal fin does not reach back to the level of the anal fin origin. The last unbranched dorsal fin ray is weakly to moderately ossified, serrated and flexible distally, with 18-26 long denticles along 50-60% of its length, narrowly spaced and moderately strong. The pelvic fin insertion is positioned posterior to first branched dorsal fin ray. The caudal fin is deeply to moderately forked with unequal sized of lobes, usually the upper lobe pointed and lower one rounded. The anal fin has its margin slightly concave or straight and does not reach back to the caudal fin base when depressed. The pelvic fin has a slightly rounded to straight margin and

does not extend back to the anal fin origin although it almost reaches it in some fish. The pectoral fin has a slightly convex to straight margin and does not extend back to the pelvic fin origin.

Dorsal fin unbranched rays 4, branched rays 8-10, modally 9, anal fin unbranched rays 3, branched rays 5, pectoral fin branched rays 16-21, and pelvic fin branched rays 8-10, modally 9. Lateral line scales 62-80, scales above lateral line 11-16, scales below lateral line 8-11 (presumably to the pelvic fin origin), scales between lateral line and anal fin origin 8-13, and caudal peduncle scales 22-31. The pelvic axillary scale is well-developed, pointed, and triangular. Scales are straight to rounded on all margins, the anterior margin with a central projection and indented dorsally and ventrally in some, with radii on all fields, numerous fine circuli, and a sub-central anterior focus. Total gill rakers number 14-21 and on the lower limb 11-14 (Jouladeh Roudbar *et al*. (2020) gave 25-27 as the gill raker count, presumably in error, as the lower count is from the original description and material herein). The longest rakers reaches the one below when depressed. Pharyngeal teeth are 2,3,4 or 5-5 or 4,3,2, the largest being the fourth major row tooth, there being a notch on the arch where the fifth tooth would be. Pharyngeal teeth are spatulate. The gut is elongate with several long coils. Total vertebrae number 44-47.

Meristic values are:- dorsal fin branched rays 8(1), 9(39) or 10(1), anal fin branched rays 5(41), pectoral fin branched rays 16(1), 17(4), 18(12), 19(18), 20(6) or 21(1), pelvic fin branched rays 9(37) or 10(4), lateral line scales 62(1), 63(-), 64(1), 65(1), 66(1), 67(1), 68(3), 69(8), 70(2), 71(3), 72(7), 73(-), 74(4), 75(6), 76(2), 77(1) or 78(1), total gill rakers 16(2), 17(3), 18(10), 19(15), 20(9) or 21(2), and total vertebrae 44(2), 45(9), 46(18) or 47(1).

**Sexual dimorphism.** Tubercles are present on males (CMNFI 1993-0126, 11 May 1993, 161.7 mm standard length), weakly developed on the body, a few larger ones below the nostrils, large ones on anal fin branched rays 3-4, and one per scale above the anal fin. In CMNFI 1993-0130 (caught in May 1993, 115.3-130.5 mm standard length) tubercles are large below the anterior eye and forward under and in advance of the nostril but not across the snout. Very fine tubercles are scattered on the top of the head. There are 1-2, usually one central, very small tubercles on the anterior back and upper flank and on the lower flank from the pelvic fin level to the caudal peduncle. The anal fin has a single row of few and large tubercles on branched rays 1-5.

**Colour.** The back, head and flanks are dark olive to brown, darker dorsally and lighter below the lateral line. The cheeks are cream or golden-green. The back and flanks can be an overall silvery and the belly white, cream or yellowish. Black or dark brown spots are scattered on the flanks anteriorly. Scales may be weakly outlined by pigment on the upper flank. The dorsal fin is dark olive to dark grey at the base and lighter at the margin. The pectoral and pelvic fins are dark yellow to orange, sometimes hyaline. The caudal fin rays are pigmented darkly, being olive to dark grey. The dorsal and caudal fins bear pigment on the rays and membranes but there are no rows of spots. The peritoneum is brown to black. Young fish have a few dark blotches or scattered spots on the body.

**Size.** Reaches 20.3 cm standard length (Jouladeh-Roudbar *et al*., 2017).

**Distribution.** This species is found in the Tigris River basin of Iran in the Aran, Chagnalnandi, Chameshk, Dinvar, Gamasiab, Gelal, Kahman, Karkheh, Kashkan, Khorram (Khorramabad), Qareh Su, Ravansar, Sarab-e Maran and Simareh rivers and Cheshmeh Javari (Jouladeh-Roudbar *et al*., 2017; Shirmohamadi *et al*., 2017; Zareian and Esmaeili, 2017; Hosseinpour *et al*., 2018). May be present in the lower Karkheh River as mapped by Jouladeh-

Roudbar *et al*. (2017) although their material was from the upper reaches of this basin (and see below under **Parasites and predators**).

**Zoogeography.** See under the genus.

**Habitat.** This species is found generally in rivers, streams and springs. Collection data included a temperature range of 18.5-24ºC, pH 6.0-6.8, river or stream width 2 m, slow to medium current, clear, clear and brown-tinged, muddy or cloudy water, mud, clay, gravel, stone or bedrock bottoms, submergent, emergent and floating vegetation, and a grassy, bushy or forested shore.

Type locality of *Capoeta shajariani*, Hamedan, Gamasiab River near Doab Village, after Jouladeh-Roudbar *et al*. (2017), Soheil Eagderi.

Habitat of *Capoeta shajariani,* Kermanshah, Gamasiab River at Darakeh (= Derkeh), Hamid Reza Esmaeili.

**Age and growth.** Zareian *et al*. (2018a) gave a *b* value of 2.937 for 9 fish, 9.0-13.1 cm total length.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** Jalali *et al*. (1995) described two new species of monogeneans, *Dactylogyrus rohdeianus* and *D. capoetae*, from fish identified as *C. damascina* and possibly *C. shajariani* caught in the Chaghalnandi River, a Karkheh River tributary north of Ahvaz.

**Economic importance.** None.

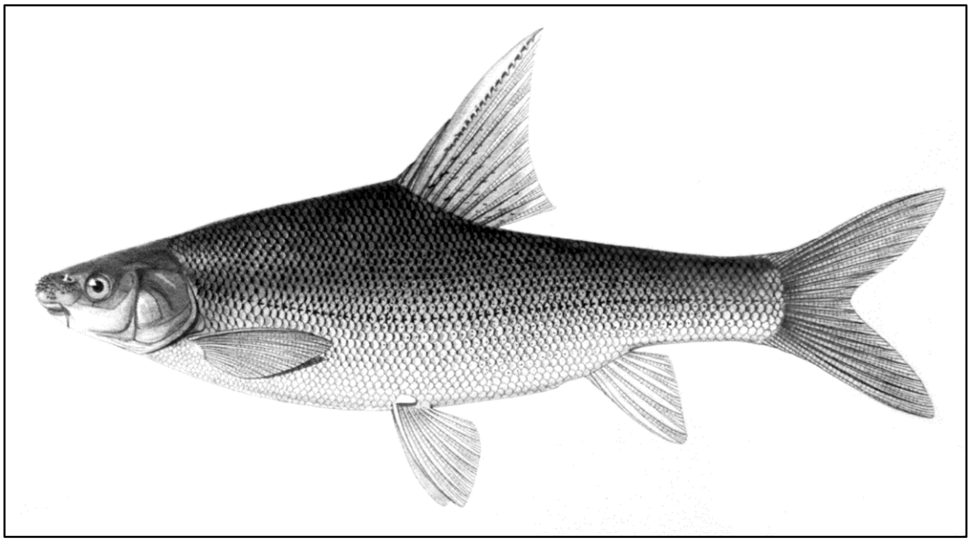
**Experimental studies.** None.

**Conservation.** Jouladeh Roudbar *et al*. (2020) listed it as of Least Concern because it is widespread and was not thought to have declined fast enough to qualify for another threat category.

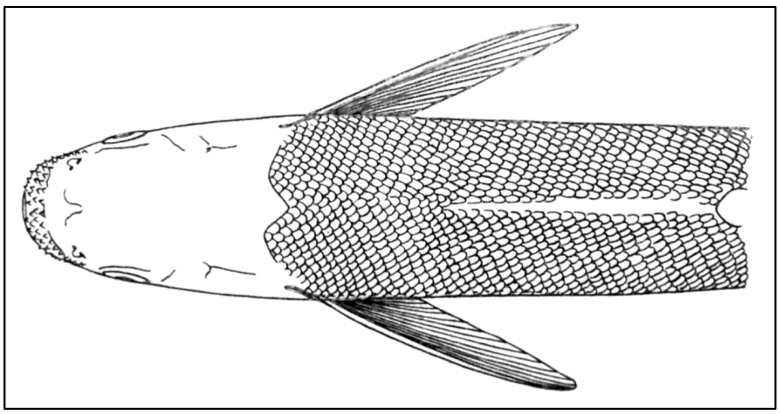
**Sources.** Jouladeh-Roudbar *et al*. (2017).

Iranian material:- CMNFI 1979-0271, 9, 47.2-137.9 mm standard length, Lorestan, river in Kashkan River drainage (33º39'N, 48º32'30"E); CMNFI 1979-0272, 1, 72.9 mm standard length, Lorestan, river at Nokhor (33º40-47'N, 48º28-45'E); CMNFI 1979-0273, 7, 66.7-137.6 mm standard length, Lorestan, Kashkan River drainage 5 km from Khorramabad (33º26'N, 48º19'E); CMNFI 1979-0274, 3, 28.9-141.8 mm standard length, Lorestan, river in Kashkan River drainage (33º27'N, 48º11'E); CMNFI 1979-0276, 5, 60.2-78.7 mm standard length, Lorestan, Chameshk River (ca. 33º19'N, ca. 47º53'30"E); CMNFI 1979-0277, 2, 116.2-133.4 mm standard length, Lorestan, Kashkan River drainage (33º30'N, 47º59'30"E); CMNFI 1979-0278, 3, 93.5-114.7 mm standard length, Lorestan, Kashkan River drainage (33º34'N, 48º01'E); CMNFI 1979-0279, 5, 115.6-155.8 mm standard length, Lorestan, Khorramabad River (33º37'N, 48º18'E); CMNFI 1979-0280, 3, 104.7-107.7 mm standard length, Lorestan, Kashkan River drainage (33º43-47'N, 48º12-15'E); CMNFI 1979-0282, 6, 110.3-130.3 mm standard length, Lorestan, river at Nurabad (34º05'N, 47º58'E); CMNFI 1979-0283, 2, 113.7-125.0 mm standard length, Kermanshah, river in Qareh Su drainage (34º21'N, 47º07'E); CMNFI 1979-0285, 3, 125.5-148.0 mm standard length, Kermanshah, Qareh Su drainage (34º26'N, 46º37'E); CMNFI 1979-0286, 7, 17.2-47.8 mm standard length, Kermanshah, Ravansar River at Ravansar (34º43'N, 46º40'E); CMNFI 1979-0287, 2, 128.2-136.1 mm standard length, Kermanshah, Cheshmeh Javari 2 km from Ravansar (ca. 34º42'N, ca. 46º40'E); CMNFI 1993-0126, 1, 161.7 mm standard length, Kermanshah, Sarab-e Yavari (34º28'N, 46º56'E); CMNFI 1993-0130, 2, 119.0-131.1 mm standard length, Kermanshah, sarabs near Kermanshah (no other locality data); CMNFI 2007-0115, 1, 51.6 mm standard length, Kermanshah, Qareh Su basin north of Kermanshah (ca. 34º34'N, ca. 46º47'E); CMNFI 2007-0117, 1, 149.9 mm standard length, Kermanshah, Gamasiab River basin near Sahneh (ca. 34º24'N, ca. 47º40'E); CMNFI 2008-0102, 3, 132.8-146.9 mm standard length, Kermanshah, sarabs near Kermanshah (no other locality data); CMNFI 2008-0151, 1, 128.4 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); CMNFI 2008-0238, 1, 198.0 mm standard length, Kermanshah, Qareh Su (33º56'42"N, 47º28'40"E); USNM 200308, 2, 37.5-47.3 mm standard length, Lorestan, Ab-e Khorramabad near Khorramabad (33º30'N, 48º13'E).

## ***Capoeta trutta***
(Heckel, 1843)



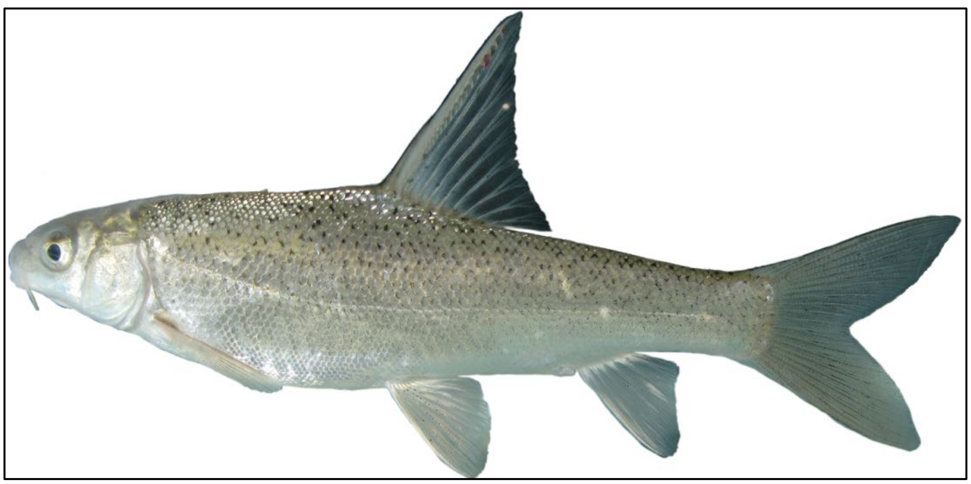
*Capoeta trutta*, 27.1 cm total length, ZISP 24052, Elvend River, Tigris basin (presumably the Alvand River of Kermanshah), after Berg (1949).



*Capoeta trutta*, head and back of above, after Berg (1949).

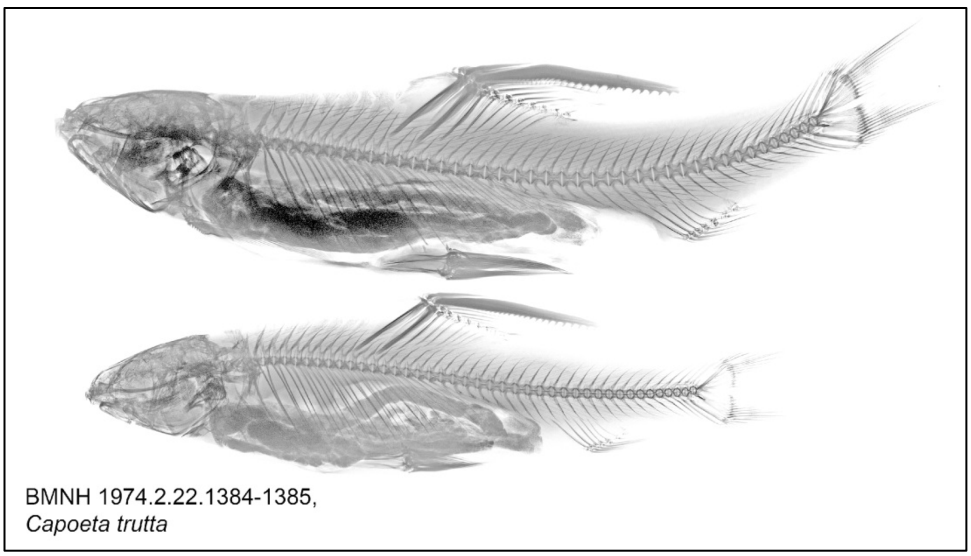
*Capoeta trutta*, Hamadan, Haramabad, Gamasiab River basin, January 2010, Keyvan Abbasi.

*Capoeta trutta*, Khuzestan, Rud-e Zard, 20 September 1995, Brian W. Coad.



*Capoeta trutta*, Iran, Hamid Reza Esmaeili.

*Capoeta trutta*, Syria, Freidhelm Krupp.




*Capoeta trutta*, Iraq, Baghdad, Natural History Museum (2014) (data.nhm.ac.uk), https://doi.org/10.5519/0002965, retrieved: 02 Feb 2019.

**Common names.** Tu'ini (and variant spellings in transliteration such as too'ini, touyeni, tunin, tuyeni, tuwini) in Khuzestan (meaning unknown, perhaps related to a place name); tu'ini gelkhorak in Khuzestan (= mud-eater); barg bidy or barg-e bidi (= willow leaf, perhaps from shape and colour), berzem, shir mahi (= milk fish), siah mahi (= black fish), siah mahi-ye khaldar or khardar (= spotted black fish), siyah mahi bale boland; kaputa (Peyghan *et al*., 2018).

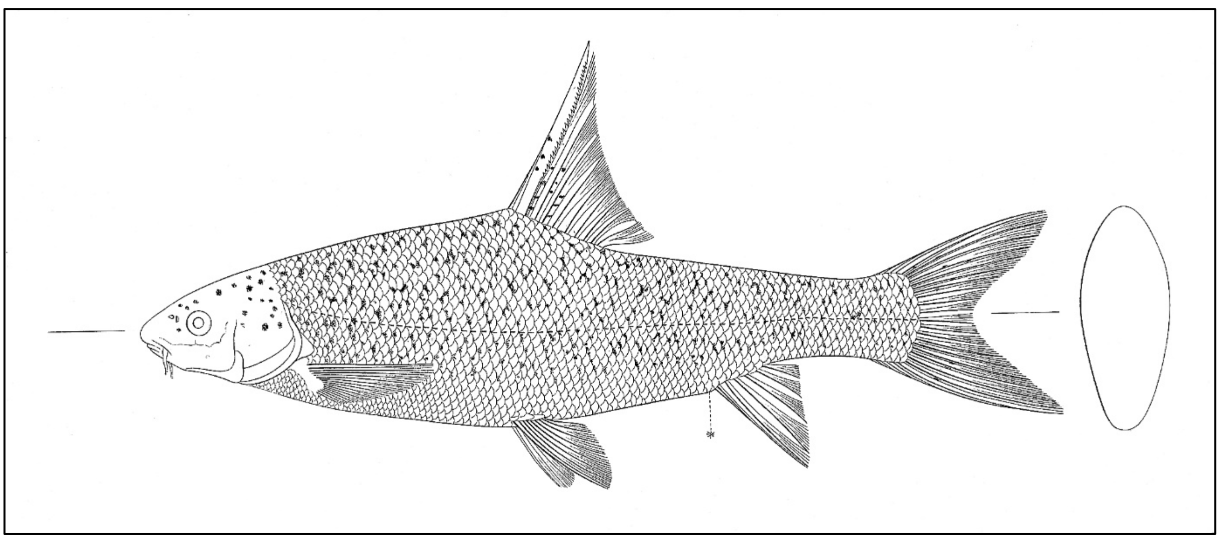
[Twena (see above), hemira (or humayara, diminutive of hamra, red or red-coloured), ethra at Mosul (Heckel (1843b), or takal handscherli (takal meaning soft or flexible presumably from its small scales, and handscherli meaning armed with a dagger or knife, from the dorsal fin spine) at Aleppo (Heckel, 1843b), tela morqat, tela moraqqat (or muraqqat, meaning spotted) (from Mikaili and Shayegh (2011)); all in Arabic; Lekeli siraz balığı in Turkish, and Bara, Berat and Çepiç (local names in eastern Turkey) (Kaya *et al*., 2016; Çiçek *et al*., 2020); longspine scraper, trout barb].

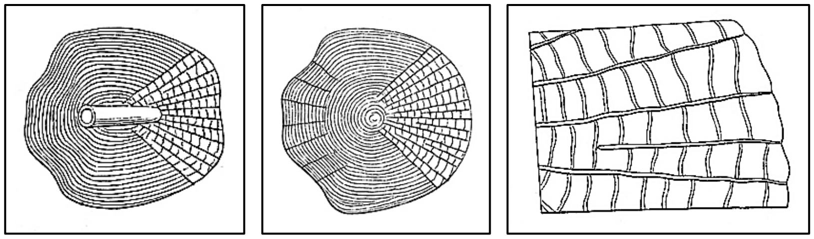
**Systematics.** Rainboth (1981) placed this species in *Schizocypris* on the basis of enlarged scales forming a split to encompass the urogenital region and a bare to partially bare

mid-dorsal strip anterior to the dorsal fin. However, the schizothoracine fishes are quite different (see accounts for *Schizothorax*, *Schizopygopsis* and *Schizocypris*) and this placement is not accepted here.

*Capoeta barroisi persica* Karaman, 1969 is an aberrant *Capoeta trutta* (Zareian *et al*., 2016) having a last dorsal fin unbranched ray shorter than the head length (usually longer than head in *C. trutta*) and an aberrant colour pattern (see Özuluğ and Freyhof (2008)). The holotype of *C. barroisi persica* is in the Zoologischen Instituts und Zoologischen Museums der Universität Hamburg (ZMH H4119, 185.2 mm standard length, Daryacheh-ye Zaribar, 35°32'N, 46°08'E, IV. 1968, W. Nümann (Bianco and Banarescu, 1982; Krupp, 1985c; examined and measured by me).

The type localities of *Scaphiodon Trutta* as given by Heckel (1843b) are “Gewässern bei Aleppo” and the “Tigris bei Mossul”. The syntypes are in the Naturhistorisches Museum Wien according to Krupp (1985c) as follows:- NMW 55935-37, 55942, 6 specimens 94-274 mm standard length from Mosul, NMW 55926, 55928, 55940-41, 7, 68-192 mm standard length from Aleppo, and in the Senckenberg Museum Frankfurt (SMF 2567 (formerly NMW), 1, 407 mm standard length, from Mosul and SMF 923 (formerly NMW), 1, 175 mm standard length, from Aleppo. Four other syntypes are under NMW 55939, one other syntype under NMW 55938 and a dried syntype under NMW 58875. Eschmeyer *et al*. (1996) listed similar material with the numbers of fish under each catalogue number detailed thus:- NMW 55926 (1), NMW 55928 (2), NMW 55935-37 (2, 2, 1), NMW 55939-42 (4, 1, 3, 1), possibly one fish in the Rijksmuseum van Natuurlijke Historie, Leiden (RMNH 3164, formerly NMW), one syntype in the Senckenberg Museum Frankfurt (SMF 923, formerly NMW) and one syntype SMF 2567 (formerly NMW), and one dried syntype from the Museum für Naturkunde, Universität Humboldt, Berlin (ZMB 8789; not located in February 2006). The catalogue in Vienna listed only five specimens although the card index in 1997 listed NMW fish as syntypes in agreement with Eschmeyer *et al*. (1996).

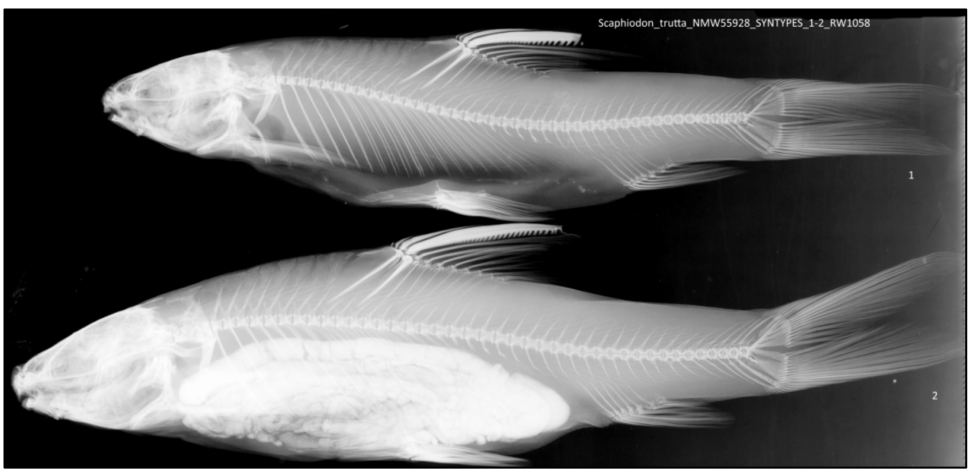




*Scaphiodon trutta*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Scaphiodon trutta*, syntype, NMW 55928, Naturhistorisches Museum, Wien.


*Scaphiodon trutta*, syntype, NMW 55928, Naturhistorisches Museum, Wien.




*Scaphiodon trutta*, syntypes, NMW 55928, Naturhistorisches Museum, Wien.

Asgardun *et al*. (2014) found morphometric and meristic differences between fish from several localities in the Tigris River basin of Iran, attributing this to the considerable geographic separation of localities. Mirzaei *et al*. (2016) used an Inter Simple Sequence Repeat analysis to study populations in Kordestan. Populations varied in their genetic diversity but there was no significant differentiation between populations. Keivany and Arab (2017) examined morphometrically 136 fish from eight rivers in the Tigris River basin of Iran and found they were separated to a great extent, this being attributed to environmental factors such as water flow and depth and to geographic distance. The most differences were in head, body and caudal peduncle depth. Parmaksiz and Eksi (2017) described the genetic diversity of Turkish populations in the Euphrates and Tigris rivers. Mehrabani *et al*. (2021) used inter-

retrotransposon amplified polymorphism markers to compare populations in Kordestan. The Marivan region was a sister clade with the regions of Baneh and Sirvan although similarities prevented its complete separation.

**Key characters.** This species is distinguished from other small-scaled *Capoeta* species (61 or more lateral line scales) by having 18 or less scales between the dorsal fin origin and the lateral line, the body and head with irregular brown to black speckles, and the dorsal fin spine is strongly developed (rarely weak), longer than the head.

**Morphology.** The body is compressed and deep, being deepest in front of the dorsal fin. The predorsal profile is straight to gently arched. The back anterior to the dorsal fin is compressed and lacks scales except near the occiput. The back may decline steeply from the dorsal fin origin posteriorly. The caudal peduncle is compressed and moderately deep. The snout is rounded and is grooved in front of the nostrils. The eye overlaps the rear half of the head in young but is positioned well into the anterior half of the head in adults. The mouth is subterminal, u-shaped in young but an arched form soon develops. There is a horny edge to the lower jaw. Lip are thin and the rostral flap almost overlaps the upper lip in adults. The barbel is thin and extends back to the anterior eye or anterior pupil level. The dorsal fin spine is very strong with large denticles in young and adults. Hanel *et al*. (1992) found 23-31 denticles or teeth on the serrated dorsal fin ray, the largest near the centre of the ray length. The dorsal fin is very high. The dorsal fin margin is concave and the dorsal fin origin is slightly anterior to the level of the pelvic fin origin. The depressed dorsal fin may reach the anal fin origin level in young but is well short of it in adults. This character seems to vary among fish of the same size. The caudal fin is moderately forked with pointed to rounded tips, the ventral tip being more rounded. The anal fin margin is emarginate or rounded and the depressed fin does not reach back to the caudal fin base. The pelvic fin is rounded and does not reach back to the anal fin origin. The pectoral fin is rounded and does not reach back to the pelvic fin origin.

Dorsal fin with 3-5 unbranched rays followed by 7-9, usually 8, branched rays, anal fin with 2-3 unbranched rays followed by 5 branched rays, pectoral fin branched rays 14-18, and pelvic fin branched rays 6-10. Scales in lateral line 61-90 (77-83 in Schöter *et al*. (2009), 61-84 in Alwan *et al*. (2016)). There is a pelvic axillary scale. Scales have a protruding anterior margin with indentations above and below but are otherwise rounded, have few anterior and posterior radii, sometimes more anterior radii than posterior but usually the reverse, fine circuli, and a subcentral anterior focus. Total gill rakers number 20-33, on the lower arm 18-25 (with lowest counts in smallest fish). The rakers reach the second raker below when appressed. Pharyngeal teeth are 2,3,4 or 5-5 or 4,3,2. Teeth are broadly spoon-shaped or spatulate at the tip, with narrow cusps and stems such that they are quite fragile. A frequency distribution of counts was not taken because of this fragility. The gut is very elongate with numerous anterior and posterior loops. Total vertebrae number 43-46. The two syntypes of *S. trutta*, NMW 55928, have 44 and 46 vertebrae and the two Iraqi fish illustrated above have 45 and 46 vertebrae. The chromosome number for fish from the Tigris River of Turkey was 2n = 150, possibly hexaploid, with 35 meta-sub-metacentric chromosomes, 40 pairs of sub-telo-acrocentric chromosomes with NF = 220 (Kılıç Demirok and Ünlü, 2001).

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(34), anal fin branched rays 5(34); pectoral fin branched rays 14(1), 15(8), 16(18), 17(6) or 18(1), pelvic fin branched rays 7(32) or 8(3), lateral line scales 68(2), 69(1), 70(1), 71(4), 72(5), 73(3), 74(5), 75(2), 76(3), 77(-), 78(3), 79(1), 80(1), 81(1), 82(-), 83(1) or 84(1), total gill rakers 22(1), 23(-), 24(5), 25(4), 26(3), 27(7), 28(8), 29(3), 30(2) or 31(1), and total vertebrae 43(1), 44(6), 45(3)

or 46(2). **Sexual dimorphism.** Fish from CMNFI 1979-0268 (138.4-141.2 mm standard length, 3 July 1977) have the following tuberculation. Males bear a single tubercle on each flank scale, sometimes two tubercles, positioned about the middle of the exposed scale or nearer the posterior edge. Flank tubercles are most evident on the upper flank and posterior lower flank. The head has small and widely scattered tubercles on the top and sides, also extending back to the dorsal fin, and large tubercles around the snout from eye to eye below the nostril level. Large tubercles occur in single files on the anal and dorsal fin rays, particularly the posterior rays, becoming apparent on the more anterior rays as tuberculation develops more highly. Anal fin tubercles are large and distal on rays 2-5. The caudal fin has fine tubercles on the fin rays.

**Colour.** The head and body and the dorsal fin (and sometimes the caudal fin) are covered with small, distinctive black spots, often c- or x-shaped. Spots are apparent through the silver flank colour. Some fish in Khuzestan lack spots but transitional specimens from fully spotted through weakly spotted to immaculate are found. Spots may extend down onto the lower flank in mid-body. Spotting in young fish is fine but distinct. Colour is brownish to yellowish or olive-green on the back with silvery-white flanks and the belly lighter, white with silvery tints. Some fish are very pale almost whitish. Upper flank scales in particular are outlined with dark pigment. The iris is orange above or mostly silvery. Lower fins are orange to yellow at the base and blackish distally, or may be orange to yellow overall. The dorsal and caudal fins are grey or hyaline with the membranes darker than the rays. The lower rays of the caudal fin have a slight orange-yellow tint. The peritoneum is dark brown to black.

**Size.** Attains at least 45.8 cm total length. Heckel (1843b) gave 1 Schuh 8 Zoll, or 52.7 cm.

**Distribution.** This species is found in the Quwayq, Orontes and Tigris-Euphrates basins, including the Iranian portion of the latter, and the Persis basin. In the Persis basin from the Fahlian, Mond, Shiv and Zohreh rivers; and in the Tigris River basin from the Abbasi, Abolabas, Abshalamzar, Ahram, A`la, Alvand, Armand, Arvand, Bahmanshir, Bala, Bazoft, Beshar, Cham Nahest, Chamzarivar, Chardoval, Choman, Deireh, Dez, Dinorab, Dinvar, Doirej, Eivan, Gahar, Gamasiab, Gangir, Garmab, Gavi (or Gaveh), Gelal, Godarkhosh, Haramabad, Jarrahi, Kahnak, Kalwi, Kangavar Kohneh, Kangir, Karkheh, Karun, Kashgan, Kashkan, Khersan, Khorram (Khorramabad), Konjanchan, Kupal, Little Zab, Lordegan, Marun, Meymeh, Murani, Qareh Su, Qeshlaq, Qipal, Raz Avar, Rowar, Sezar, Shui, Shur, Simareh, Sirvan, Talkhab, Tang-e Shib, Zard and Zimakan rivers, the Bisheh-Dalan, Gamasiab and Haramabad wetlands and the Dez, Karkheh and Qeshlaq dams (K. Abbasi, see photograph above; Molnár and Jalali, 1992; Baska and Masoumian, 1996; Barzegar and Jalali Jafari, 2006; Eskandari *et al*., 2007; Ramin and Owfi, 2008; Sadeghinejade Masouleh, 2008; Abbasi *et al*., 2009; Alwan, 2010; Biokani *et al*., 2011; Patimar and Farzi, 2011; Bahrami Kamangar *et al*., 2012a, 2012b; Bozorgnia *et al*., 2012; Javaheri Baboli *et al*., 2012; Levin *et al*., 2012; Oğuz *et al*., 2012; Poria *et al*., 2012, 2013, 2014, 2015; Biukani *et al*., 2013; Mojoudi *et al*., 2013; Pirani *et al*., 2013; Alijanpor *et al*., 2014; Asgardun *et al*., 2014, 2015; Banaee and Naderi, 2014; Dadashi *et al*., 2014; Javaheri Baboli and Taghavi Niya, 2014; Khoramian *et al*., 2014b; Khoshnood, 2014; Marammazi *et al*., 2014; Ramin *et al*., 2014; Reyahi-Khoram *et al*., 2014; Zare and Kaboodvandpour, 2014; Abdolhahi, 2015; Esmaeili *et al*., 2015; Fazeli *et al*., 2015; Mansouri *et al*., 2015; Taghavi Niya and Velayatzadeh, 2015; Taghavi Niya *et al*., 2015, 2017; Tavakol *et al*., 2015; Zamaniannejad *et al*., 2015; Alizadeh Marzenaki *et al*., 2016; Alwan *et al*., 2016; Ghanavi *et al*., 2016; Keivany and Zamani-Faradonbe, 2016; Radkhah and

Nowferesti, 2016a; Taghiyan *et al*., 2016; Zareian *et al*., 2016; Arab and Keivany 2017; Azizi *et al*., 2017; Jouladeh Roudbar *et al*., 2017; Keivany and Arab, 2017; Sadeghinejad Masouleh *et al*., 2017; Zadmajid, 2017; Zakeri *et al*., 2017; Darvishi *et al*., 2018; Peyghan *et al*., 2018; Sadeghinejad Masouleh and Abbasi, 2018b; Fatemi *et al*., 2019; Golchin Manshadi *et al*., 2019; Hasankhani *et al*., 2019; Mehrabani *et al*., 2021).

**Zoogeography.** See also above under genus. This species separated from other members of the *C. trutta* species group about 1.33 MYA (Zareian *et al*., 2018).

**Habitat.** This species is found in rivers, streams, dams, wetlands and brackish waters. Marammazi (1994) considered it to be stenohaline but nonetheless more widely distributed than stenohaline *Barbus* (= *Mesopotamichthys*) *sharpeyi* in the Zohreh River which drains to the northern Persian Gulf (Persis basin). Ramin and Owfi (2008) noted that it is the most abundant species in the Dez River basin. Javaheri Baboli *et al*. (2012) reported it from the saline Shur River in the Karun River basin. Taghavi Niya *et al*. (2017) examined the effect of water temperature, salinity, conductivity, total length and body weight on some growth and reproduction parameters in the Shour (= Shur) River. They found total weight in most years had a positive effect on reproduction effort while in contrast water temperature had a negative effect on $L_t$ in years 2, 5 and 6. Only in year 3 fish did electrical conductivity have a negative effect on $L_{t,}$ and generally water temperature was the primary factor affecting the growth and reproductive characteristics.

In the Kashkan River, Lorestan this species had the highest frequency, 1,485 fish out of 4,207 caught comprising 18 species (Sadeghinejad Masouleh *et al*., 2017). In the Simareh River this species dominated at eight stations and was about 31% of the fish there.

Habitat of *Capoeta trutta* (and *Arabibarbus grypus, Capoeta* sp., *Carasobarbus luteus, Cyprinion macrostomus, Garra rufa* and *Luciobarbus barbulus* among cyprinoids), CMNFI 2008-0120, Khuzestan, Zard Rud at Bagh-e Malek, 20 September 1995, Brian W. Coad.

**Age and growth.** Patimar and Farzi (2011) observed a maximum age of $6^+$ years in 366 fish, 10.5-34.7 cm total length, from the Meymeh River of western Iran. The male:female sex ratio was 1:1.35 and length-weight relationships were TL = $0.0266TW^{2.7134}$ for males, TL = $0.0258TW^{2.7251}$ for females and TL = $0.026TW^{2.7217}$ for the population (TL and TW should be reversed). von Bertalanffy parameters were $L_\infty$ = 45.86 mm, $k$ = 0.14 year-1, $t_0$ = -1.15 and $\acute{\varphi}$ = 5.68 for males, 50.79, 0.13, -1.45 and 5.81 for females, and 48.6, 013, -1.28 and 5.72 for the population.

Javaheri Baboli *et al*. (2012) found 268 fish from the Shur River in the Karun River basin had a length-weight relationship W = $0.0094TL^{3.0003}$ in females and W = $0.0089TL^{3.0149}$ in males, showing isometric growth in both sexes. The maximum condition factor was in September and the lowest in April, with no difference between sexes. The mean condition factor was 0.92. Taghavi Niya (2014) investigated 815 fish from the Shur River and found fish up to $6^+$ years with two- to three-year-olds dominant (over 70% of the total aged). Taghavi Niya *et al*. (2015) also reported on the 815 fish, 9.5-29.5 cm total length, from the Shur River and found a significantly different male:female sex ratio of 1:1.96, age range was <1-6 years with two- to three-year-old fish dominant and females heavier and larger than males in all age groups, length-weight relationship was W = $0.0115L^{2.9475}$ in males and W = $0.0096L^{3.0025}$ in females, von Bertalanffy growth equation was $L_t = 24.5(1-e^{-0.333(t + 2.54)})$ for males and for $L_t = 36.4(1-e^{-0.129(t + 4.02)})$ females, and growth performance index was estimated at $\Phi$ = 2.301 in males and $\Phi$ = 2.223 in females.

Poria *et al*. (2012) found 6 age groups in 225 fish from the Alvand River in Kermanshah. The male:female sex ratio was 1.27:1 and females were longer and heavier than males. Javaheri Baboli and Khoramian *et al*. (2014b) found 193 Dez Dam fish had a total length and weight relationship of LogW = -1.097 + 2.94LogL for males, LogW = -1.377 + 3.036LogL for females and LogW = -1.67 + 2.98LogL for all fish, indicating isometric growth. Condition factors were 0.76 for males, 0.88 for females and 0.83 for all fish.

Poria *et al*. (2014) examined 252 fish from the Gamasiab River and found fish aged 1-5 years with a male:female sex ratio of 1.96:1, and females were longer and heavier than males except for one-year-old males. Alijanpor *et al*. (2014) reviewed the population structure of 224 fish from two stations in the Gamasiab River. Age groups were $0^+$ to $4^+$ years with $1^+$ fish dominant. The length-weight relationships for the two sample stations were W = 2.85TL-4.09 and W = 2.94TL-4.4 negatively allometric (*sic*), and von Bertalanffy growth equations were $L_\infty$ = 204.151, k = 0.56 and $t_0$ = -1.68 and $L_\infty$ = 211.489, k = 0.59 and $t_0$ = -0.74. Poria *et al*. (2015) reported 252 Gamasiab River fish were up to age 5 and 225 Alvand River fish were up to age 6 years, range of total length in Alvand and Gamasiab rivers was 17.1-42.6 and 16.6-31.3 cm respectively, the *b* values were 2.246 in males and 2.72 in females for the Gamasiab and 2.741 and 2.91 in the Alvand, negatively allometric in both rivers and sexes. Alvand and Gamasiab fish attained 426 mm and 313 mm total length respectively and weight 798 g and 352 g, indicating more stable ecological conditions and food abundance in the Alvand. Radkhah *et al*. (2015) found a *b* value of 3.054 (positive allometric growth) and a condition factor of 0.93 for 40 fish, 10.5-19.8 cm total length, from the Gamasiab River.

Esmaeili *et al*. (2014) gave a *b* value for 77 fish from the Tigris River and Persis basins, 8.6-20.6 cm total length, as 2.74. Asgardun *et al*. (2015) examined fish from the Kangir River and found negative allometric growth. Fazeli *et al*. (2015) found 103 fish, 8.3-28.0 cm total length, from the Seymarreh (= Simareh) River reached $4^+$ years, had a male:female sex ratio of 1:1.9, a *b* parameter of 3.09, females were generally larger than males, the most frequent size

group was 20-24 cm, and condition factor peaked in the spring at 1.28 and decreased in the summer. Sadeghinejad Masouleh and Abbasi (2018b) found growth was isometric in the Simareh River. Keivany and Zamani-Faradonbe (2016) gave a *b* value of 2.96 for 21 fish, 3.7-11.6 cm total length, from the Zohreh River. Radkhah and Nowferesti (2016a) found *b* values for 42 Kangir and 20 Seimare River (= Simareh) fish, 60.3-210.3 cm total length, were 2.69 and 2.85 and condition factors (K) were 1.06 and 1.17 suggesting a favourable condition. Arab and Keivany (2017) examined 223 fish from four rivers in the Persis basin and eight rivers in the Tigris River basin, finding generally a positive allometric pattern although fish from the Ahram, Doirej, Eivan Abasi, Sirvan and Zimakan rivers showed negative allometry indicating unsuitable feeding conditions. Valikhani *et al*. (2020) combined fish from the Shadegan Wetland and the Dez and Karkheh rivers and reported a *b* value of 3.05 (isometric growth) and a condition factor of 5.49 (*sic*) for 367 fish (3.4-17.9 cm total length).

The majority of the population studied by Ünlü (1991) in the Tigris River in Turkey were in age groups 2 and 3 although males lived to age 7 and females age 10. Females were usually longer and heavier than males of the same age. Males comprised 41.26% and females 58.74% of this population. In a stream in the Euphrates River drainage of Turkey, Gul *et al*. (1996) found fish to live for 8 years with 60-90% of the fish in age groups 1 to 3. Females comprised 53.3% and males 46.7% of the population. Kalkan (2008) studied a population in the Karakaya Dam on the Turkish Euphrates River. Maximum age was 7 years, age groups 4 and 6 were mostly females whereas age group 3 was mostly male, age-length, age-weight and length-weight formulae were given, and the average growth condition factor was 1.3 for females and 1.28 for males. Aydın *et al*. (2012) examined 259 fish from Keban Dam Lake and 281 fish from Karakaya Dam Lake, Turkey and found an age range from 1 to 8 years, von Bertalanffy equations of the population in Keban Dam Lake were $L_t = 91.79\,[1\text{-}e^{-0.0600(t+2.2866)}]$ in females, $L_t = 95.30[1\text{-}e^{-0.0541(t+2.4362)}]$ in males, and $L_t = 92.57[1\text{-}e^{-0.0577(t+2.3032)}]$ in all individuals, the length-weight relationship was $W = 0.0151L^{2.9274}$ in females, $W = 0.017L^{2.9019}$ in males, and $W = 0.0168L^{2.9032}$ in all individuals; and in Karakaya Dam Lake the relationships respectively were $L_t = 89.92\,[1\text{-}e^{-0.0616(t+2.2045)}]$, $L_t = 92.39[1\text{-}e^{-0.0567(t+2.3262)}]$, $L_t = 92.57[1\text{-}e^{-0.0577(t+2.3032)}]$, $W = 0.0210L^{2.84}$, $W = 0.0237L^{2.8078}$, and $W = 0.0211L^{2.8271}$. Dartay and Gül (2014) found a length-weight relationship for 29 Keban Dam, Turkey fish, 32.3-45.8 cm total length, of $W = 0.0087L^{3.079}$. Bilici *et al*. (2017) found age groups of 1-6 years, gave a length-weight relationship of log W = -4.6845 + 2.9303 log fork length for females and log W = -4.7784 + 2.9746 log fork length for males, von Bertalanffy growth equations were $L_t = 35.36[1\text{-}e^{-0.082817(t+4.82738)}]$ for females and were $L_t = 28.82[1\text{-}e^{-0.1238(t+4.40235)}]$ for males, the somatic condition was 1.4434 for females and 1.4722 for males, in the Tigris River of Turkey.

**Food.** Gut contents include diatoms, green algae and large amounts of sand. Fazeli *et al*. (2015) found fish from the Seymarreh (= Simareh) River had a relative gut length (4.6) and Zihler's Index (2.11) indicative of herbivory. Zakeri *et al*. (2017) examined 79 fish from the Sezar River and found a relative gut length 9.97 indicating herbivory, mean condition factor was 1.44, mean index of fullness was 1.41 and the mean vacuity index was 478.08. All foods were periphyton unicellular algae, the genera *Navicula*, *Cymbella*, *Diatoma* and *Nitzschia* being the main food items, with 18 other genera as supplementary and incidental foods.

**Reproduction.** Fish from Khuzestan examined by me had well-developed eggs on 30 January while adult fish taken on 7 July were not in reproductive condition. In Iran fish spawn in March-May (Abdoli, 2000). Fish from the Meymeh River examined by Patimar and Farzi (2011) spawned in these months and had a maximum egg diameter of 1.9 mm, a mean absolute

fecundity of 7,594 eggs and a mean relative fecundity of 70 eggs/g body weight. Poria *et al*. (2012, 2014) found Alvand River fish had a mean gonadosomatic index of 1.71 (1.41 for males and 2.02 for females) and a mean condition factor of 1.13 with no significant difference between males and females. Mean egg diameter was 0.8 mm (range 0.11-2.02 mm), mean absolute fecundity was 15,233 eggs (range 2,980-26,756 eggs), and mean relative fecundity was 37.25 eggs. May was determined as the spawning time and the reproduction period was March to July based on the gonadosomatic indices.

Poria *et al*. (2014, 2014) examined Gamasiab River fish and found a sex ratio of 1.96:1 in favour of males, a mean absolute fecundity of 7,756 eggs (range 1,920-17,505), a mean relative fecundity of 50.65 eggs, an average gonadosomatic index of 5.18 for males and 3.44 for females (significantly different, with a maximum of 9.23 for females in May and a mean of 3.64), a mean egg diameter of 0.9 mm (range 0.12-1.9 mm, maximum in May), and reproduction occurred from March to June, peaking in May.

Fazeli *et al*. (2015) found fish from the Seymarreh (= Simareh) River spawned once in spring based on the gonadosomatic index and the Dobriyal Index. Javaheri Baboli and Taghavi Niya (2014) investigated fish from the Shur River and found a male:female sex ratio of 1:1.96, a single spawning mode lasted from February to April, most males matured at 1 year and females at 2 years, egg diameter reached 1.16 mm in April, and average fecundity was 2,591 for $1^+$ females and 11,552 eggs for $6^+$ year females. Zadmajid (2017) compared two- and three-year-old males in the Gheshlagh (= Qeshlaq) River during the June-July breeding season. Motility duration and sperm density were significantly higher in the two-year-olds while the gonadosomatic index was higher in three-year-olds. Other reproductive parameters were not significantly different.

Spawning in both the Tigris and Euphrates rivers in Turkey took place in May-June. Males matured at age 2 and females at age 3 in both rivers. Ripe egg size in the Tigris varied between 1.33 and 2.11 mm and egg numbers between 4,713 and 18,240. Ripe eggs in the Euphrates attained 1.04 mm and the maximum number of eggs per gramme of gonads was 666 (Patimar and Farzi, 2011). Bilici *et al*. (2016) examined fish from the Turkish Tigris River and found the female:male sex ratio was 1:0.47, the reproduction period was between May and July, the water temperature at this period was between 21.4°C and 31°C, age at first maturity was 3 years for females and 2 years for males, the mean estimated fecundity was 5,285 (9,227 maximum) eggs, relative fecundity was 90.83 eggs/g with a mean of 32.15, and maximum egg diameter was 0.91 mm.

Dogu *et al*. (2013) described the embryonic and larval development of this species, with fertilised eggs reaching 1.95 mm and the first hatching at 60 hours after insemination.

**Parasites and predators.** Molnár and Jalali (1992) reported the monogenean *Dactylogyrus pulcher* from this species in the Dez River of Khuzestan. Gussev *et al*. (1993a) described a new species of monogenean from this species in the Dez River, *Dactylogyrus microcirrus*. Baska and Masoumian (1996) described two new species of Myxosporea from fish caught in the Karun River at Ahvaz, *Myxobolus molnari* taken from the gills and *Myxobolus mokhayeri* taken from between the soft rays of the fins. The latter species is named after Dr. Baba Mokhayer, an internationally renowned Iranian professor. The new species are of minor pathological importance as the infections are of low intensity and prevalence. Masoumian and Pazooki (1999) listed *Myxobolus molnari* and *M. mokhayeri* from this species from localities in Khuzestan. Peyghan *et al*. (2001) recorded *Neoechinorhynchus* sp. and *Rhabdocona* sp. from fish from Khorramabad rivers. Barzegar and Jalali (2009) reviewed

crustacean parasites in Iran and found *Lernaea* sp. and *Tracheliastes polycolpus* on this species. Oğuz *et al*. (2012) recorded the acanthocephalan *Neoechinorhynchus zabensis* from fish in the Dez River. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Neoechinorhynchus zabensis* (Dez River), *Neoechinorhynchus* sp., (Khorramabad River) and *Pallisentis cholodkowskyi* (Vahdat (= Qeshlaq) Dam, Kordestan). Peyghan *et al*. (2018) recorded *Ichthyophthirius multifilis* and *Neoechinorhynchus spiramusculari* from this fish in the Dez River.

**Economic importance.** Peyghan *et al*. (2001) reported that this is an economically important species with a good market value in the Khorramabad region in Iran. Sarab Ghamish villagers ate this species from the Qeshlaq Dam (Zare and Kaboodvandpour, 2014). Poria *et al*. (2013, 2013) stated that it was locally important in the Alvand and Gamasiab rivers and found interrelationships between various morphometric variables and body weight, useful in breeding programmes. Poria *et al*. (2013) examined body weight in relation to biometric traits in fish from the Alvand River, finding standard length, head length and body width were important for determining body weight in males. This data could be used in breeding programmes as a measure of direct selection for fish with better body weight traits.

Duman and Duman (1996) gave the nutritional value of *Capoeta trutta* from Keban Dam in Turkey and Bilici *et al*. (2017) stated that it is a commercial species in the Tigris River of Turkey.

**Experimental studies.** Mojoudi *et al*. (2013) found that fish from the Dez River had zinc levels in muscle and liver tissue within acceptable limits but concentrations of cadmium and lead were higher than international standards. Agricultural and domestic effluents were the main pollution sources. Zare and Kaboodvandpour (2014) found high bioaccumulation and bio-magnification of mercury in fish from the Qeshlaq Dam and recommended local consumers should not eat more than 1,182 g of this fish weekly without accounting for other potential mercury sources in their food intake. Mansouri *et al*. (2015) investigated levels of the heavy metals cadmium, chromium, copper, lead and zinc in edible parts of fish from the Sirvan River, finding them to be below the level of concern for human consumption.

Zadmajid (2016) examined the effects of human chorionic gonadotropin and ovaprim (a commercial spawning inducing agent) as hormonal treatments for wild-caught male fish. Ovaprim had the highest efficiency, increasing, for example, the gonadosomatic index and sperm volume. Dogu *et al*. (2013) detailed embryonic and larval development of this species after artificial fertilisation.

Bahrami Kamangar *et al*. (2012b) provided baseline haematological and biochemical indices for this species in Gheshlagh (= Qeshlaq) Dam, Kordestan that could be used in health monitoring.

**Conservation.** This species does not appear in need of conservation but its biology is too poorly known in Iran to be certain. Listed as of Least Concern by the IUCN (2015). Kalkan (2008) recommended prohibition of fishing in Turkey during March-August and fish under 22.62 cm should not be retained.

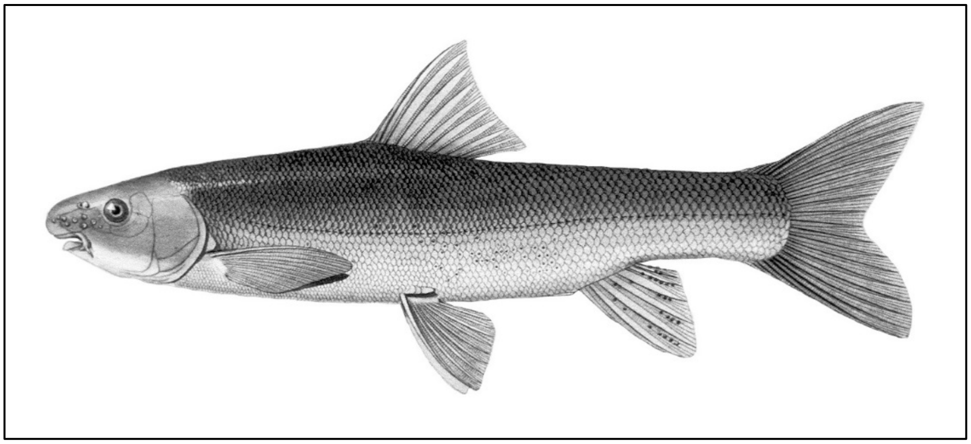
**Sources.** Type material:- *Capoeta barroisi persica* (ZMH H4119).

Iranian material:- CMNFI 1979-0268, 3, 115.7-141.2 mm standard length, Lorestan, between Nowqan and Khorramabad (no other locality data); CMNFI 1979-0269, 2, 114.1-144.1 mm standard length, Lorestan, between Nowqan and Khorramabad (no other locality data); CMNFI 1979-0367, 2, 29.7-54.1 mm standard length, Khuzestan, Meymeh River 11 km north of Dehloran (32º44'30"N, 47º09'30"E); CMNFI 1979-0368, 8, 36.3-67.9 mm standard

length Khuzestan, Karkheh River (32º24'30"N, 48º09'E); CMNFI 1979-0376, 1, 55.2 mm standard length, Khuzestan, river tributary to Karkheh River (32º48'30"N, 48º04'30"E); CMNFI 1979-0384, 1, 218.4 mm standard length, Khuzestan, river in Ab-e Shur drainage (32º00'N, 49º07'E); CMNFI 1991-0153, 2, 153.8-217.2 mm standard length, Khuzestan, Zohreh River (no other locality data); CMNFI 1995-0009A, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 2007-0100, 1, 136.7 mm standard length, West Azarbayjan, Kalwi Chay near Piranshahr (ca. 36º44'N, ca. 45º10'E); CMNFI 2007-0109, 10, 61.3-167.4 mm standard length, Kordestan, Qeshlaq River basin north of Sanandaj (ca. 35º33'N, ca. 47º08'E); CMNFI 2007-0110, 3, 96.6-160.3 mm standard length, Kordestan, Yuzi Dar River basin (ca. 35º05'N, ca. 46º56'E); CMNFI 2007-0113, 1, 74.8 mm standard length, Kermanshah, Razavar (= Raz Avar) River, Qareh Su tributary (ca. 34º25'N, ca. 47º01'E); CMNFI 2007-0116, 1, 95.9 mm standard length, Kermanshah, Gamasiab River west of Sahneh (ca. 34º28'N, ca. 47º36'E); CMNFI 2007-0117, 2, 153.8-217.2 mm standard length, Kermanshah, Gamasiab River near Sahneh (ca. 34º24'N, ca. 47º40'E); CMNFI 2008-0120, not kept, Khuzestan, Rud Zard at Rud Zard (31º22'N, 49º43'E); CMNFI 2008-0121, not kept, Khuzestan, Zard Rud at Bagh-e Malek (31º32'N, 49º55'E); CMNFI 2008-0130, not kept, Khuzestan, stream at Kupal (31º15'N, 49º10'E); CMNFI 2008-0132, 2, 190.2-194.0 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); CMNFI 2008-0182, 1, 193.8 mm standard length, Chahar Mahall and Bakhtiari, Ab-e Bazoft Sofla (31º38'06"N, 50º28'30"E); CMNFI 2008-0184, 1, 88.0 mm standard length, Chahar Mahall and Bakhtiari, Armand River (31º37'N, 50º47'E); ZMH 2511, 1, 319.0 mm standard length, Kermanshah, Karasu-Gamasiab-Seymarreh (= Qareh Su-Gamasiab-Simareh, no other locality data).

Comparative material:- BM(NH) 1931.12.21:8, 1, 113.5 mm standard length, Iraq, Mosul (36º20'N, 43º08'E); BM(NH) 1968.12.13:376-390, 15, 35.6-123.3 mm standard length, Syria, Euphrates River at Mayadine (35º01'N, 40º27'E); BM(NH) 1974.2.22:1374-1377, 4, 66.3-91.2 mm standard length, Iraq, Baghdad (33º21'N, 44º25'E); BM(NH) 1974.2.22:1382, 1, 86.1 mm standard length, Iraq, Baghdad (33º21'N, 44º25'E); BM(NH) 1974.2.22:1388-1389, 2, 259.4-273.3 mm standard length, Iraq, Tigris River at Samarra (34º12'N, 43º52'E); CMNFI 1980-1036, 1, 155.3 mm standard length, Turkey, Elazig, Keban Dam on Euphrates River (ca. 38º41'N, ca. 30º14'E); CMNFI 1988-0148, 1, 183.2 mm standard length, Turkey, Elazig, Keban Dam on Euphrates River (ca. 38º41'N, ca. 30º14'E); CMNFI 1993-0166, 1, 233.9 mm standard length, Iraq, Tigris River (no other locality data).

## ***Capoeta umbla***
(Heckel, 1843)



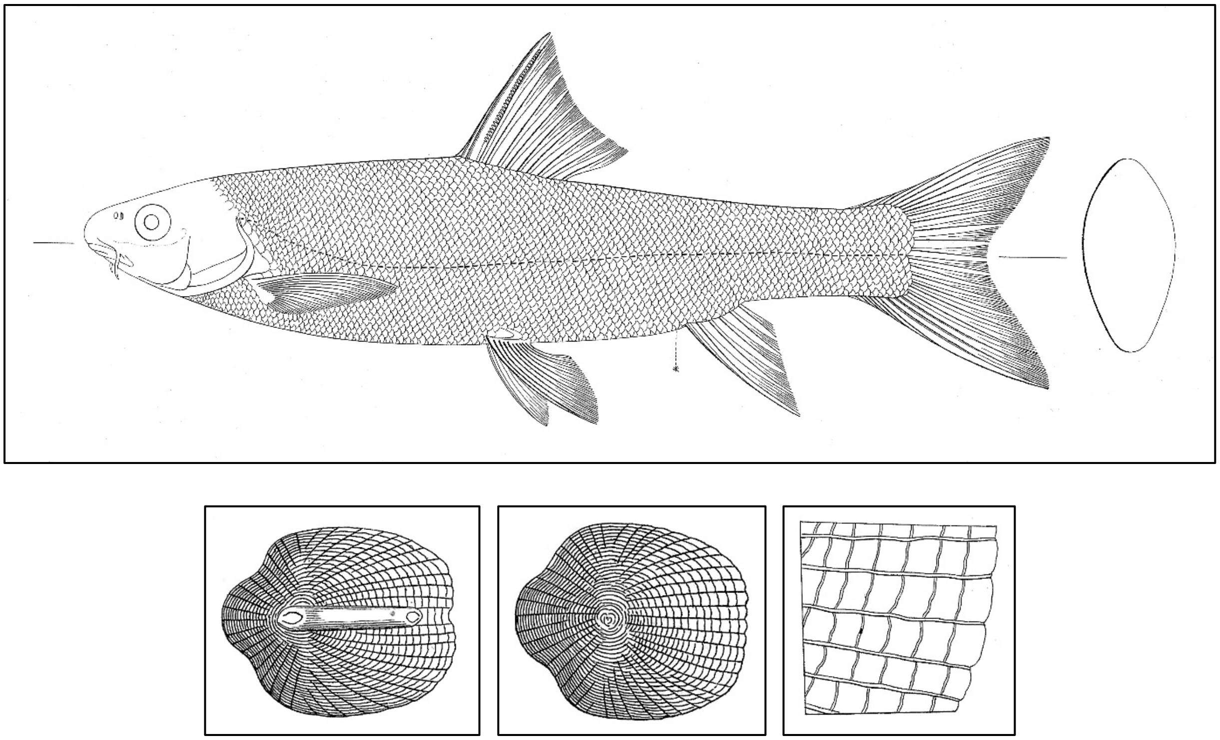
*Capoeta umbla*, 30.0 cm total length, ZISP 24027, Kordestan (presumably), Sazan River, tributary of the Sirvan, Tigris River basin, after Berg (1949).

*Capoeta umbla*, Kordestan, Garran River, a tributary of Sirvan River, Hamid Reza Esmaeili.

**Common names.** Siyah mahi Tigris.

[Siraz and Siraz balığı (in Turkish), and Sarı balık and Zeruke (= yellow fish) (local names in eastern Turkey) (Kaya *et al*., 2016; Çiçek *et al*., 2020); Tigris scraper].

**Systematics.** Syntypes of *Scaphiodon umbla* are under NMW 55932, 184 mm standard length, NMW 55933, 177 mm standard length, Tigris at Mosul. The Ichthyology Type Database, NMW (downloaded 9 July 2016), also listed NMW 55934 (184 mm standard length), Tigris at Mosul, as a syntype, and two stuffed specimens under NMW 79373 and 79374 and one stuffed specimen under SMF 6777 (from NMW, F. Krupp, pers. comm., 1985; ca. 262.3 mm standard length) are also considered as syntypes (*Catalog of Fishes*, downloaded 6 July 2016). The catalogue in Vienna listed two fish in spirits and two fish stuffed and the card index in 1997 listed as syntypes NMW 55932-33 and 79373-74 (dried).



*Scaphiodon umbla*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

*Scaphiodon umbla*, syntype, NMW 55932, Naturhistorisches Museum, Wien.

*Scaphiodon umbla*, syntype, NMW 55933, Naturhistorisches Museum, Wien.

This species was formerly considered as a subspecies or synonym of *C. damascina* (see Alwan (2011) for summary). It is distinguished from that species (not now known for certain from Iran) which has 11-20, modally 14-15 scales between the dorsal fin origin and lateral line, 7-14, modally 9-10 scales between the anal fin origin and the lateral line, and by 61-91 lateral line scales (Alwan, 2010; Esmaeili *et al*., 2016).

**Key characters.** This species is distinguished from other small-scaled *Capoeta* species (61 or more lateral line scales) by having 18-25, modally 19-20, scales between the dorsal fin origin and lateral line.

**Morphology.** The body is elongate and slightly compressed. The greatest body depth is at the level of the dorsal fin origin or slightly in front. The predorsal body profile is smoothly convex to the dorsal fin origin and may be almost straight. A nuchal hump is present in well-fed specimens. The dorsal head profile is straight to gently convex. The caudal peduncle is compressed and moderately deep. The posterior margin of the eye is slightly behind the mid-point of the head. The snout is rounded to pointed and the mouth is ventral. The snout overlaps part of the upper lip, particularly in the middle. The lower lip is covered with a sharp-edged, horny sheath and its anterior margin is straight or rounded to almost crescent-shaped. The upper lip is thick at the corners. The barbel extends back level with the middle of the eye or just beyond. The dorsal fin origin is well anterior to the pelvic fin origin and its outer margin is usually concave. The last unbranched dorsal fin ray is weakly to moderately ossified, soft and flexible at the tip, serrated in half to three-quarters of its length, with large denticles. The depressed dorsal fin does not extend back level with anal fin origin. The caudal fin is deeply forked and its tips are pointed or sometimes with the lower lobe more rounded. The anal fin outer margin is straight or slightly convex and the fin may, or may not, reach the caudal fin base when depressed (see under **Sexual dimorphism**). The pelvic fin does not extend to the anal fin origin and the outer fin margin is straight or slightly rounded. The pectoral fin does not extend to the pelvic fin origin, and the outer fin margin is usually slightly convex.

The dorsal fin has 4-6 unbranched and 8-10, mode 9 branched rays, the anal fin has 3 unbranched and 5 branched rays, the pectoral has 16-22 branched rays, and the pelvic fin has 8-12 branched rays. Scales are very small, 72-104 scales in the lateral-line series (81-93 in Turan *et al*. (2006), 72-93 with syntypes 90 and 91 in Schöter *et al*. (2009), 83-99 in Kaya *et al*. (2016)), scales between the dorsal fin origin and the lateral line 18-25, scales between anal fin origin and the lateral line 10-15, scales around the caudal peduncle 31-39, and the ventral midline and pectoral region are covered with deeply embedded scales of reduced size. Scales are almost a horizontal oval with a shallowly rounded posterior margin, rounded dorsal and ventral margins, and a protruding central area to the posterior margin or smoothly rounded. Radii are found on all fields, those on the lateral fields being curved, and the focus is subcentral anterior. Circuli are relatively few in number. Gill rakers are slightly hooked, and number 17-23 total with 12-16 on the lower limb, and the longest raker reaches beyond its neighbour when appressed. Pharyngeal teeth are arranged in three rows 2,3,5-5,3,2 (or 2,3,4,-4,3,2 in Kaya *et al*. (2016)) and very similar in shape to those of *C. damascina*. The fifth tooth may be reduced to a nub. The teeth are scalloped with medium crowns. Total vertebrae number 46-50. Jawad and Alwan (2020) gave total vertebrae as 42-47 but this may not include the four Weberian vertebrae and so the range would extend up to 51 total vertebrae.

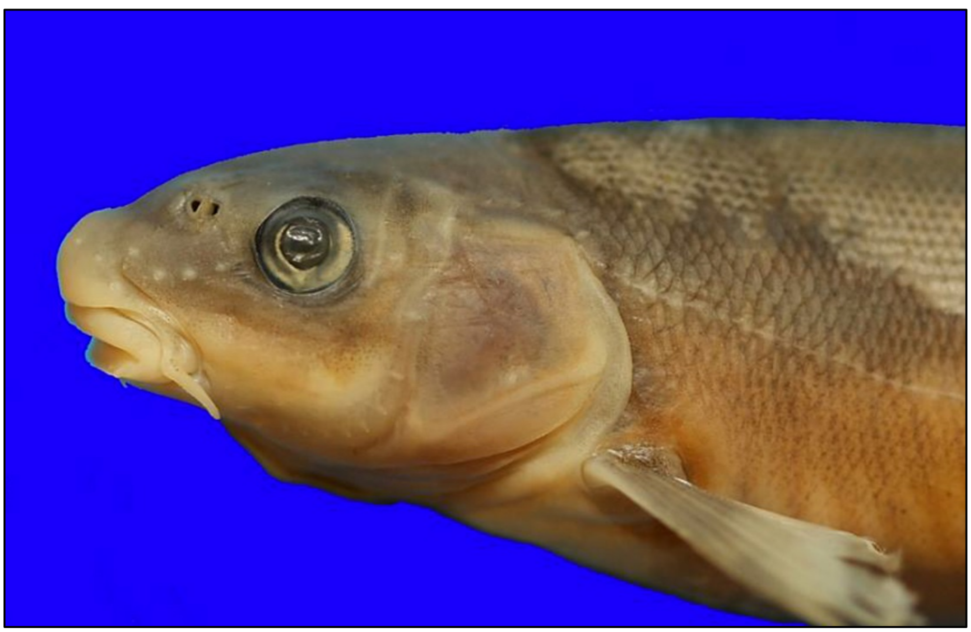
Dorsal fin unbranched rays 4(3), 5(23) or 6(1), dorsal fin branched rays 8(11), 9(41) or 10(5), anal fin unbranched rays 3(30), anal fin branched rays 5(57), pectoral fin branched rays 18(3), 19(16), 20(17), 21(6) or 22(1), and pelvic fin branched rays 9(18), 10(35) or 11(3).

Lateral line scales 80(1), 81(1), 82(-), 83(2), 84(3), 85(-), 86(4), 87(3), 88(2), 89(1), 90(4), 91(5), 92(3), 93(4), 94(4), 95(5), 96(2), 97(2), 98(1), 99(1), 100(1), 101(1), 102(-), 103(-) or 104(1). Gill rakers on the lower limb 15(3) or 16(9) and total gill rakers 18(5), 19(4), 20(2), 21(12), 22(2) or 23(1). Total vertebrae 46(3), 47(8), 48(7), 49(1) or 50(1). Fish identified as *C. c. umbla* from the Tigris River of Turkey had 2n = 150, possibly hexaploid, with 43 meta-sub-metacentric chromosomes, 32 pairs of sub-telo-acrocentric chromosomes with NF = 236 (Kiliç Demirok and Ünlü, 2001).

Çiçek *et al*. (2016) documented differences in scale shape of fish from the Turkish Tigris River according to sex, season and age. Çiçek *et al*. (2017) discriminated this species from *C. trutta* in the Turkish Tigris River using scale morphometry. Jawad and Alwan (2020) gave comparative details of the vertebral column and dorsal, anal and caudal fins in a study of the osteology of the *Capoeta damascina* species complex.

**Sexual dimorphism.** Males have well-developed tubercles on the sides of the snout from eye to eye below the nostrils, and on the back, on the body above the lateral line to the caudal fin origin, on the lateral line with one tubercle per scale but not on every scale, on the area above the anal fin, and on anal fin rays. Unculi are present on the snout of some males. In very rare cases, females bear a small number of breeding tubercles on the sides of the snout and in the area above the anal fin.

The tip of anal fin reaches to or beyond the vertical of the caudal fin base in females and to about two-thirds of the caudal peduncle in males.



*Capoeta umbla*, 148.0 mm standard length, ZM-CBSU Z290, Kordestan, Garran River, 25 August 2015, Hamid Reza Esmaeili.

**Colour.** Live fish are a shiny golden-brown or yellow on the back of the head and body, darker dorsally and becoming lighter below the lateral line. Fins are golden-yellowish. Preserved fish are brown or brownish-grey dorsally, with the lower half of the body yellow or yellowish-white or even very similar to more dorsal areas. Fins are yellow or brownish-yellow. Fin rays are pigmented and also the membranes in the caudal fin. Juveniles have obvious black flank spots but spotting is absent in adults (Alwan, 2010; Esmaeili *et al*., 2016; Elp *et al*.,

2018).

**Size.** Reaches 47.6 cm total length (Çoban *et al*., 2013).

**Distribution.** This species is found in the Tigris-Euphrates River system of Iran, Iraq, Syria and Turkey and the Quwayq River in Syria, including the upper reaches of the Tigris River system in southeastern Turkey adjacent to Iran (Kaya *et al*., 2016). Recorded from the Garan (= Garran), Leyleh and Sazan rivers in the Sirvan River basin, Kordestan (Berg, 1949; Esmaeili *et al*., 2016; Jouladeh-Roudbar *et al*., 2020), the Little Zab River near Sardasht (Jouladeh-Roudbar *et al*., 2017; Shirmohamadi *et al*., 2017; Çiçek *et al*., 2021), and the Choman River in Kordestan (Alavi-Yeganeh *et al*., 2018). Also, in the Kalwi, Qeshlaq and Yuzi Dar rivers. GenBank has this species at Pirandasht in West Azarbayjan, at Baneh, Kamyaran and Sarab-e Ghamesh in Kordestan, at Paveh in Kermanshah, and at Meymeh in Ilam. Biokani *et al*. (2011) recorded it from the Gamasiab River but this needs confirmation.

**Zoogeography.** See above under the genus. This species belongs to the *Capoeta damascina* species complex.

**Habitat.** This species is found in rivers, streams, lakes, dams, and marshes.

Habitat of *Capoeta umbla*, Kordestan, Garran River, a tributary of Sirvan River, Hamid Reza Esmaeili.

**Age and growth.** Alavi-Yeganeh *et al*. (2018) found a total length *b* value of 1.172 (and 0.929 for standard length) for 101 fish, 3.2-25.3 cm total length, from the Choman River. Zareian *et al*. (2018a) gave a *b* value of 3.061 for 33 Iranian fish, 2.9-20.9 cm total length.

Fish from Hazar Lake, Turkey were examined by Şen *et al*. (2001) who found a strong correlation between otolith length and fish length in 251 specimens, by Şen *et al*. (2002) who back-calculated fork lengths from otolith lengths and found age groups 3 to 10 years, by Çoban *et al*. (2013) on 364 fish, 11.0-47.6 cm total length, who recorded a length-weight relationship of $W = 0.07xTL^{2.39}$, von Bertalanffy parameters $L_\infty = 53.77$ cm, $K = 0.16$, $t_0 = -1.84$, and $W_\infty =$

957.38 g, natural mortality (M) = 0.363, fishing mortality (F) = 0.349 and total mortality (Z) = 0.712, annual catch was 25,721 kg or 107,544 individuals and mean fish size was 28.7 cm and 239.4 g, estimated stock size by mark-recapture methods was 91,601 kg and 382,627 individuals and by length-based cohort analysis 95,256 g and 358,105 individuals, and estimated sustainable yield was 27,070 kg, and by Yüksel *et al*. (2014) who found a catch-per-unit-effort was 1.55 kg/day/gill net, the amount of stock being estimated at 37,781 kg and population size was 38,649 kg and the fishing method was found to be appropriate.

Kocaman *et al*. (2002) found 118 fish, 12.1-31.2 cm average fork length, from the Tuzla Stream in the Karasu River basin of Turkey had ages 1 to 6 years, males matured at age 3 and females at age 4 years, males outnumbered females and female:male ratio was 0.686:1, *b* value was 2.828 for females and 2.715 for males, and average condition factor was 1.169. Türkmen *et al*. (2002) examined 1,171 fish, 6.7-40.2 cm fork length, from the Aşkale Region of the Karasu River, Turkey and found an overall male:female ratio was 1.3:1. Growth parameters were $L_\infty$ = 42.3 cm, k = 0.1457 and $t_0$ = -0.98 for males $L_\infty$ = 45.7 cm, k = 0.1393 and $t_0$ = -0.83 for females. Length-weight relationships were *b* = 2.936 for males and *b* = 2.991 for females. Aras *et al*. (2009) compared 630 Tercan Dam and Tuzla Stream fish, 9.5-35.3 cm, from Turkey finding similar length distributions, *b* values (2.45, 2.67), condition factors (1.17,1.18) and von Bertalanffy constants $L_\infty$ (41.11, 52.15), K (0.137, 0.201) and $t_0$ (-0.54, -1.351). Dartay and Gül (2014) found a length-weight relationship for 22 Keban Dam, Turkey fish, 28.4-43.5 cm total length, of $W = 0.0086L^{3.065}$.

**Food.** Presumably similar to other members of the genus.

**Reproduction.** Türkmen *et al*. (2002) found fish from the Aşkale Region of the Karasu River, Turkey had fecundities of 3,754-38,859 eggs for fish 21.0-40.2 cm fork length, spawning occurred in May-July, and males reached maturity at 16.9 cm while for females maturity was at 20.9 cm. Çoban *et al*. (2013) examined fish from Lake Hazar, Turkey and found males matured at age group 2 (23.31 cm) and females at age group 3 (25.61), gonadosomatic indices were highest in April for both sexes and spawning took place between April-June, egg diameters reached 2.0 mm with the highest values in May, and fecundity reached 15,624 eggs.

**Parasites and predators.** None reported from Iran.

**Economic importance.** This species has been made into sausages in Turkey although they were of low commercial importance because of intermuscular bones and availability of other products (Özpolat *et al*., 2014).

**Experimental studies.** None.

**Conservation.** Listed as of Least Concern by the IUCN (2015).

**Sources.** Based in part on references cited above.

Iranian material:- CMNFI 2007-0100, 3, 48.4-97.4 mm standard length, West Azarbayjan, Kalwi Chay near Piranshahr (ca. 36º44'N, ca. 45º10'E); CMNFI 2007-0108, 8, 121.0-174.3 mm standard length, Kordestan, Qeshlaq River basin north of Sanandaj (ca. 35º33'N, ca. 47º08'E); CMNFI 2007-0109, 4, 96.4-129.4 mm standard length, Kordestan, Qeshlaq River basin south of Sanandaj (ca. 35º16'N, ca. 47º01'E); CMNFI 2007-0110, 15, 79.4-141.3 mm standard length, Kordestan, Yuzi Dar River basin (ca. 35º05'N, ca. 46º56'E).

## Genus *Carasobarbus*

Karaman, 1971

This genus comprises 9-10 species found in the Middle East and North Africa. Three species are reported from Iran. Some of the past literature on this genus appeared under *Barbus* (*q.v.*), and *Kosswigobarbus* (see *Carasobarbus kosswigi*).

The genus was diagnosed by Borkenhagen and Krupp (2013) and Borkenhagen (2017b) as having a medium body size, a smooth, last dorsal fin unbranched ray, modally 9 or 10 dorsal fin branched rays and 6 anal fin branched rays, large, shield-shaped scales with numerous parallel radii, a lateral line scale count of 25-39 (here 23-41 from my counts), pharyngeal teeth hooked at their tips with a count of 2,3,5-5,3,2 or 2,3,4-4,3,2, and 1-2 pairs of barbels. The species are hexaploids. Two of the Iranian species (*kosswigi* and *sublimus*) have a spatulate lower jaw and a distinctive median lower lip lobe and their relationship is confirmed by molecular data (Borkenhagen *et al*., 2011). Borkenhagen (2017a) attributed the split of *kosswigi* and *sublimus* from other *Carasobarbus* species to ecological factors because of the mouth shape and adaptation to fast-flowing waters. The split cannot be correlated with any palaeogeographical event (Borkenhagen, 2017b).

One species (C. *luteus*) is an important food fish and has been studied in some detail. The other two species in Iran are poorly known ecologically.

The following table summarises some key distinguishing characters of the Iranian species of *Carasobarbus*.

| Species/Characters | Barbels | Lateral line scales | Lower lip lobe | Distribution |
|---|---|---|---|---|
| *C. kosswigi* | 2 pairs | 31-41 | Present | Tigris |
| *C. luteus* | 1 (rarely 2) pairs | 23-41 | Absent | Hormuz, Kor, Maharlu, Persis, Tigris |
| *C. sublimus* | 2 pairs | 24-29 | Present | Persis, Tigris |

### *Carasobarbus kosswigi*
(Ladiges, 1960)

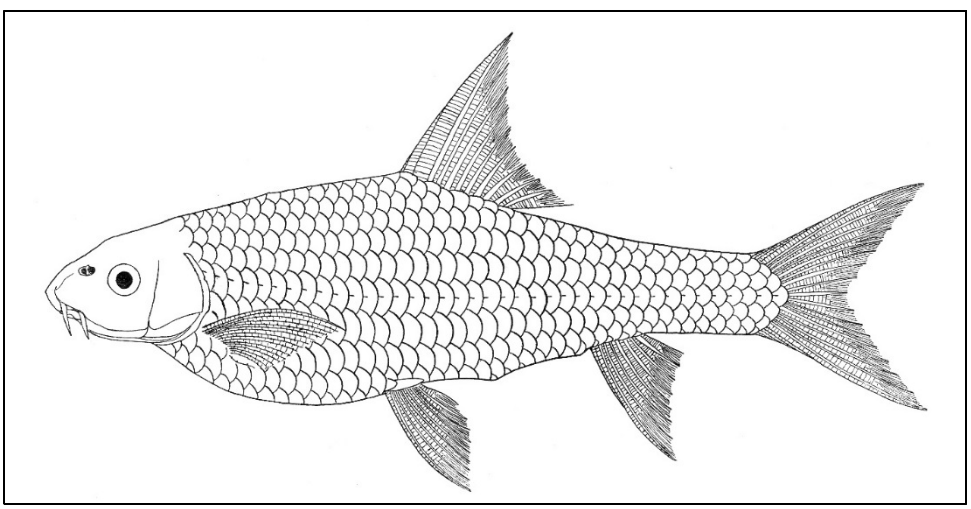
*Carasobarbus kosswigi*, Khuzestan, Karkheh River, after Borkenhagen and Krupp (2103).

*Carasobarbus kosswigi*, 107.1 mm standard length,
ventral head,
modified after Borkenhagen and Krupp (2013).

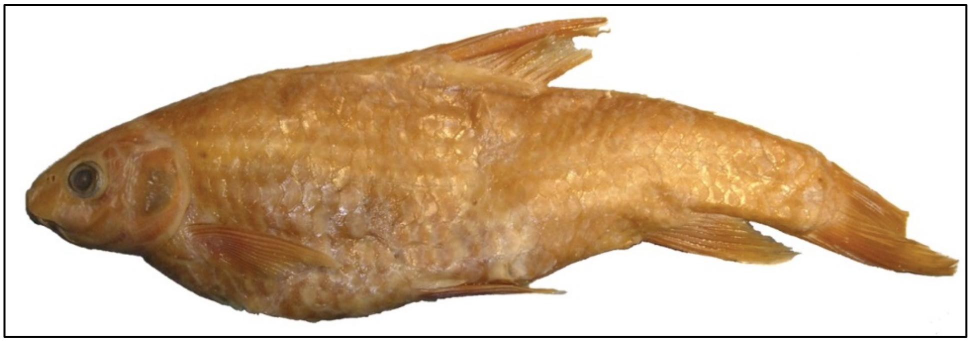
**Common names**. Abu henej, abu hanaj or abohanj (= father of the hook or spine; possibly abu hanash or abu henesh, father of the snake), shebeh shirbot (= resembling shirbot).

[Kosswig bıyıklı balığı (Turkish) after Kaya *et al*. (2016); kiss-lips himri, Kosswig's barb, Kosswig's barbel].

**Systematics.** This species was described as *Cyclocheilichthys kosswigi* from the "Batman suyu". The holotype is possibly a female, 162.7 mm, Turkey, Siirt Province, Batman suyu (the Batman stream enters the Tigris River at 37°47.30"N, 41°00'E near Batman). The holotype is in the Zoologischen Instituts und Zoologischen Museums der Universität Hamburg (ZMH H1148). The genus *Cyclocheilichthys* Bleeker, 1859 is found only in Southeast Asia.



*Cyclocheilichthys kosswigi*, holotype, ZMH H1148, after Ladiges (1960).


*Cyclocheilichthys kosswigi*, holotype, ZMH H1148, after Borkenhagen and Krupp (2103).

A new and monotypic genus, *Kosswigobarbus*, was erected for this species by Karaman (1971) but this was synonymised with *Barbus* by Coad (1982e). Karaman (1971) distinguished the genus on the basis of the fin ray characters, a well-developed rostral flap, numerous fine pores on the head, and a large lachrymal bone. However, Bănărescu (1997) and Ekmekçi and Banarescu (1998) considered *Kosswigobarbus* to be valid. Borkenhagen (2005) stated that *kosswigi* and *sublimus* should be placed in *Barbus* (*Carasobarbus*) or *Carasobarbus*, favouring treating *Carasobarbus* as a subgenus until *Barbus* was revised thoroughly. Borkenhagen *et al*. (2011) included the two species in the genus *Carasobarbus*. Khaefi and Esmaeili (2014) using cytochrome *b* found *Kosswigobarbus* to be very close to *Carasobarbus* and probably not a valid genus.

Borkenhagen *et al*. (2011) found the number of nucleotide differences between individuals of this species to be surprisingly high, attributing this to rarity and small populations which give rise to genetic drift and founder effects. Both this species and *C. sublimus* live in small mountain streams and were considered to be less likely to migrate through lowland rivers than, for example, *Carasobarbus luteus*, a more widespread and generalist species.

**Key characters.** This species is characterised by having two pairs of thin barbels, a narrow mouth with a spatulate lower lip and a lower lip median lobe, 6 anal fin branched rays, the last dorsal fin unbranched ray strong and sharp-edged but smooth, markedly longer than the head, 9-11 dorsal fin branched rays, large scales (usually 38 or less in the lateral line and usually 14-16 around the caudal peduncle), and a deep and compressed body.

**Morphology.** The body is compressed and deep, deepest at the dorsal fin origin. The caudal peduncle is compressed and deep. The predorsal profile is convex and the snout is rounded after a straight head. The rostral flap shows variable development, sometimes overlapping the upper lip to become visible in ventral view and other times not so well-developed. Lips are thick, continuous and fleshy and there is a large median lobe to the lower lip. The mouth is small, ventral and u-shaped. The barbels are thin and the anterior one extends back to between the nostrils and the eye and the posterior one to mid-eye. The rear of the eye is at the beginning of the anterior half of the head. The dorsal fin origin lies over, slightly behind or slightly in advance of the pelvic fin origin. The dorsal fin margin is strongly concave and the last dorsal fin unbranched ray is a very strong spine without teeth. The depressed dorsal fin reaches back to a level over the end of, or to the middle of, the anal fin. In large fish the dorsal fin is on a ridge above the back. The caudal fin is deeply forked with the upper lobe pointed and the lower lobe rounded, thicker and bigger. The anal fin is long, distally straight or rounded and may overlap the caudal fin base or fall short. The pelvic fin margin is rounded to almost straight and does not extend back to the anus. The pectoral fin is emarginate and almost

extends back to the pelvic fin origin or falls short.

Dorsal fin unbranched rays 4, branched rays 9-11, anal fin unbranched rays 2-3, branched rays 6, pectoral fin branched rays 14-17, and pelvic fin branched rays 7-8. Lateral line scales 31-41. Scales are regularly arranged over the body. A low sheath of scales is found at the base of the anal and dorsal fins, being most evident anteriorly, and enclosing the anal papilla. There is a pelvic axillary scale. Scale shape varies from squarish to rounded with the vertical dimension greater than the horizontal, the posterior margin is rounded and short or protrudes, the dorsal and ventral margins are narrow and are straight to gently rounded, the anterior corners are abrupt but rounded, and the anterior margin has a central protrusion with an indentation above and below or is wavy. Anterior scale radii are few (5-11 in five scales from one specimen 126.6 mm SL) while posterior radii are numerous (35-40). There is a scaled keel or ridge before the dorsal fin as the back narrows dorsally. Total gill rakers 10-16, reaching to or just beyond the raker below when appressed. Pharyngeal teeth are 2,3,5-5,3,2, 2,3,5-4,3,2, 2,3,4-5,3,2 and 2,3,4-4,3,2. The teeth are quite small even in the largest specimens. Teeth are hooked at the tip and strongly recurved there, teeth are conical and have a small, concave to irregular or even rounded grinding surface below the tip. The fifth and most anterior tooth in the main row is small to minute in most fish and may be absent but this is not size related as both large and small specimens have or lack this tooth. The gut is elongate and coiled. Total vertebrae number 39-40 (Jouladeh-Roudbar *et al*. (2020) gave 43-46 vertebrae).

Meristic data from Iranian and other Tigris-Euphrates specimens:- dorsal fin branched rays 9(5), 10(34) or 11(1), anal fin branched rays 6(40) (not 7 as in the original description), pectoral fin branched rays 15(2), 16(6) or 17(4), and pelvic fin branched rays 7(1) or 8(11). Lateral line scales 31(2), 32(1), 33(2), 34(6), 35(3), 36(1), 37(1), 38(1) or 41(1) (Kuru’s (1975) range is 32-36), scales above the lateral line 6(7), 7(10) or 8(1), scales below the lateral line 5(5) or 6(13), scales between lateral line and pelvic fin 4(11) or 5(1), predorsal scale rows 11(1), 12(2), 13(5), 14(3) or 15(1), and caudal peduncle scales 13(2), 14(2), 15(6) or 16(2). Total gill rakers 10(2), 11(2), 12(3), 13(3) or 14(1). Pharyngeal teeth 2,3,5-5,3,2(4), 2,3,4-4,3,2(3) or 2,3,4-5,3,2(1). Total vertebrae 39(5), 40(4). Jawad *et al*. (2017) gave details on the vertebrae.

**Sexual dimorphism.** Sample sizes are too small to investigate accurately.

**Colour.** Overall colour is silvery with the back darker. The abdomen is almost white. Preserved and freshly-caught material is an overall yellowish-brown. Upper flank scales are outlined by pigment, most evidently anteriorly on each scale. Fins are lightly pigmented with scattered melanophores on both rays and membranes with some concentration on dorsal fin membranes although the extent varies individually. Fins may have reddish tinges. The peritoneum is black.

**Size.** Reaches 19.4 cm total length (the holotype), 17.9 cm standard length in Iran.

**Distribution.** This species is found in the Tigris-Euphrates basin of Turkey, Syria, Iraq and Iran. In Iran found in the Tigris River basin including the Alvand, Balarud, Dez, Gahar, Gamasiab, Karkheh, Karun, Kashkan, Khersan, Khorramabad, Nahr-e Shavor and Simareh rivers (Coad, 1982e; Coad and Najafpour, 1997; Abdoli, 2000; Borkenhagen and Krupp, 2013; Ramin *et al*., 2014; IUCN, 2015). It may also occur in the Zohreh River (Gh. Izadi, pers. comm., 2001; Fatemi *et al*., 2019), although a specimen from there (CMNFI 2008-0260) appears to be *C*. *sublimus*.

**Zoogeography.** Karaman (1971) considered that the closest relatives of this species are to be found in the Indo-Malayan region. Borkenhagen (2005) defined the genus *Carasobarbus*

as a monophyletic group with species in Southwest Arabia, the Levant and the Tigris-Euphrates basin. See also under the genus *Mesopotamichthys* for general comments on the Torini.

**Habitat.** This species is found in large rivers in Iran that, however, in mid-summer are more stream-like in water flow. Collections are from the plains of Khuzestan and from altitudes in excess of 1,600 m in the Zagros Mountains. Temperatures in early July ranged from 21 to 23°C. One locality was polluted and others were cloudy or muddy. The river beds were composed of stones.

**Age and growth.** Unknown.

**Food.** The elongate gut and black peritoneum suggest a plant component to the diet but examination of two gut contents by me revealed insect remains including chironomid larvae.

**Reproduction.** Unknown.

**Parasites and predators.** Sohrabi and Jalali (2002) reported the nematode *Schulmanella petruchewskii* from the liver of this species caught in the Dez River.

**Economic importance.** This species is too rare in Iran to be of any economic importance.

**Experimental studies.** None.

**Conservation.** Recommendations are difficult to make since the ecological requirements of this species are unknown. A preference for fast water may cause it to be impacted by dams (Borkenhagen and Krupp, 2013). It appears to be rare but this may only be inadequate sampling techniques. Further collections in addition to the holotype have been made in southern Anatolian Turkey (Kuru, 1978-1979) but it does not seem to be common. Endangered in Turkey (Fricke *et al*., 2007). Listed as Vulnerable by the IUCN (2015) through its rarity, dam construction, water abstraction and pollution. Freyhof *et al*. (2020) considered it to be threatened by widespread pollution, water abstraction and dam construction.

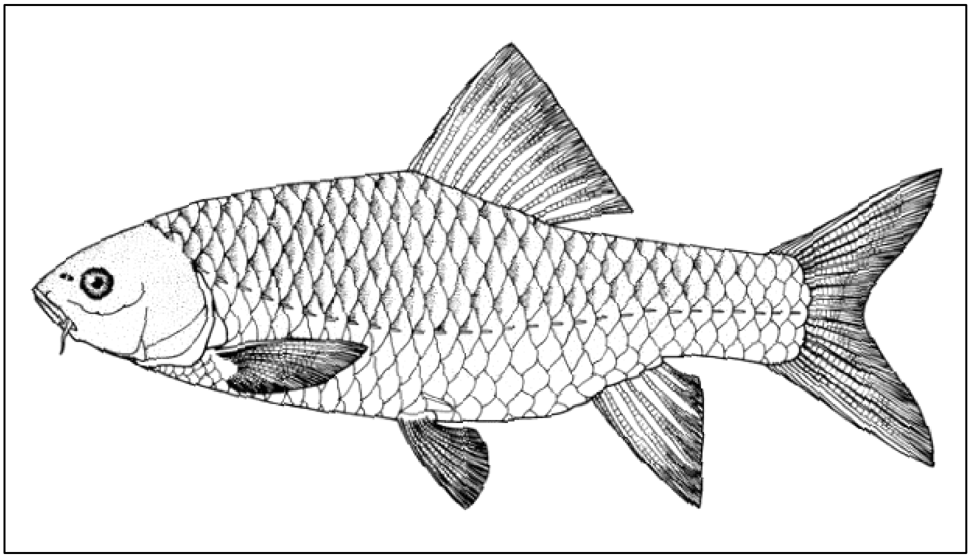
**Sources.** Some counts were from Kuru (1975) on Turkish material.

Type material:- *Cyclocheilichthys kosswigi* (ZMH H1148).

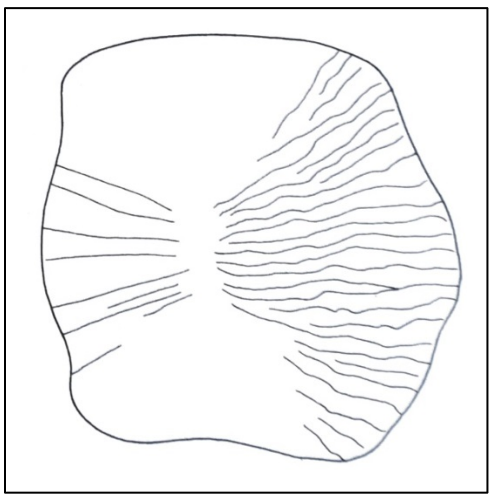
Iranian material:- CMNFI 1979-0275, 1, 126.6 mm standard length, Lorestan, Kashkan River 2 km from Ma'mulan (33º25'N, 47º58'E); CMNFI 1979-0289, 1, 103.5 mm standard length, Kermanshah, river in Diyala River drainage (34º28'N, 45º52'E); CMNFI 1979-0290, 2, 120.1-122.1 mm standard length, Kermanshah, river in Qasr-e Shirin (34º31'N, 45º35'E); CMNFI 1979-0368, 1, 73.1 mm standard length, Khuzestan, Karkheh River (32º24'30"N, 48º09'E); CMNFI 1993-0149, 1, 170.2 mm standard length, Khuzestan, Karun River (no other locality data); CMNFI 2008-0132, 1, 140.2 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); CMNFI 2008-0133, 173.0 mm standard length, Khuzestan, Karkheh River near Shush (32º12'N, 48º20'E); CMNFI 2008-0134, 2, 155.0-179.5 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); CMNFI 2008-0151, 1, 103.1 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); CMNFI 2008-0159, 1, 109.6 mm standard length, Iran (no other locality data).

Comparative material:- BM(NH) 1974.2.22:1281, 1, 31.2 mm standard length, Iraq, Al Hadithah (34º07'N, 42º23'E); BM(NH) 1974.2.22:1292-1296, 4, 35.5-98.5 mm standard length, Iraq, Al Hadithah (34º07'N, 42º23'E).

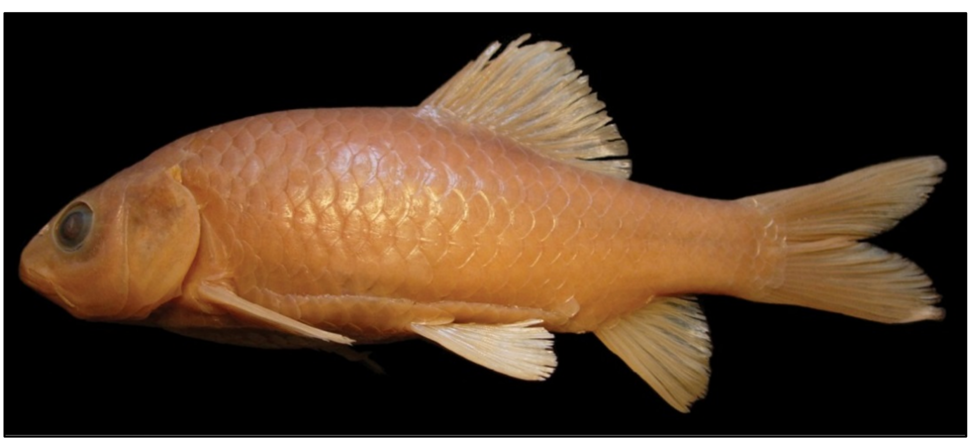
### *Carasobarbus luteus*
(Heckel, 1843)



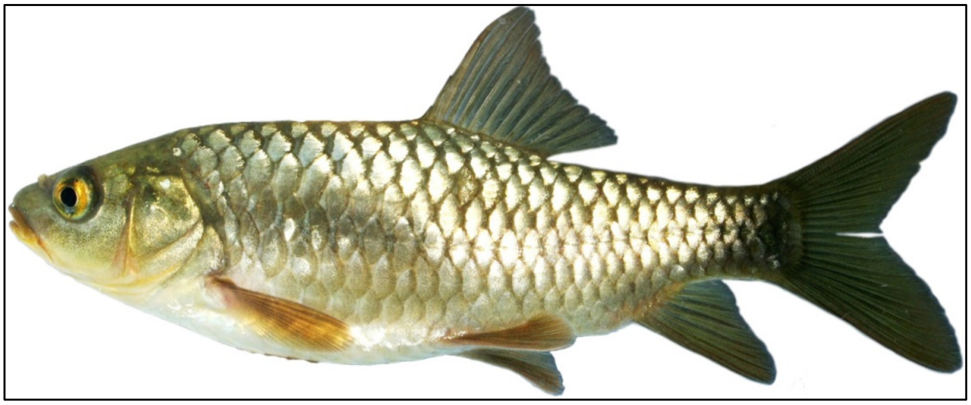
*Carasobarbus luteus*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Carasobarbus luteus*, scale, Freidhelm Krupp.

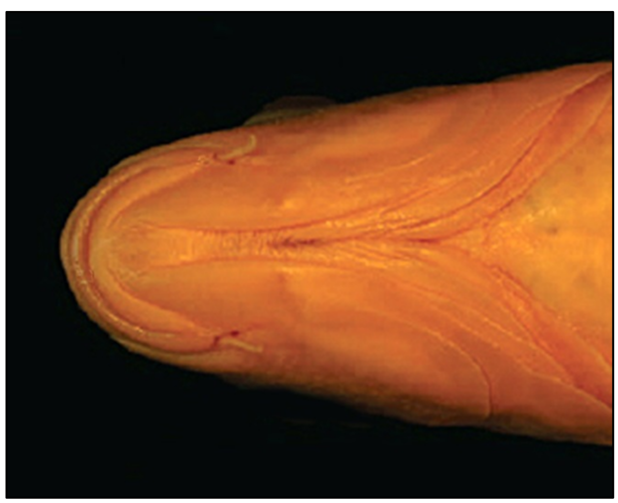


*Carasobarbus luteus*, CMNFI 1979-0187, Hormozgan, Sar Khun,
after Borkenhagen and Krupp (2103).



*Carasobarbus luteus*, Hormozgan, Kul River basin spring, Hamid Reza Esmaeili.

*Carasobarbus luteus*, Syria, Khabur River, Freidhelm Krupp.

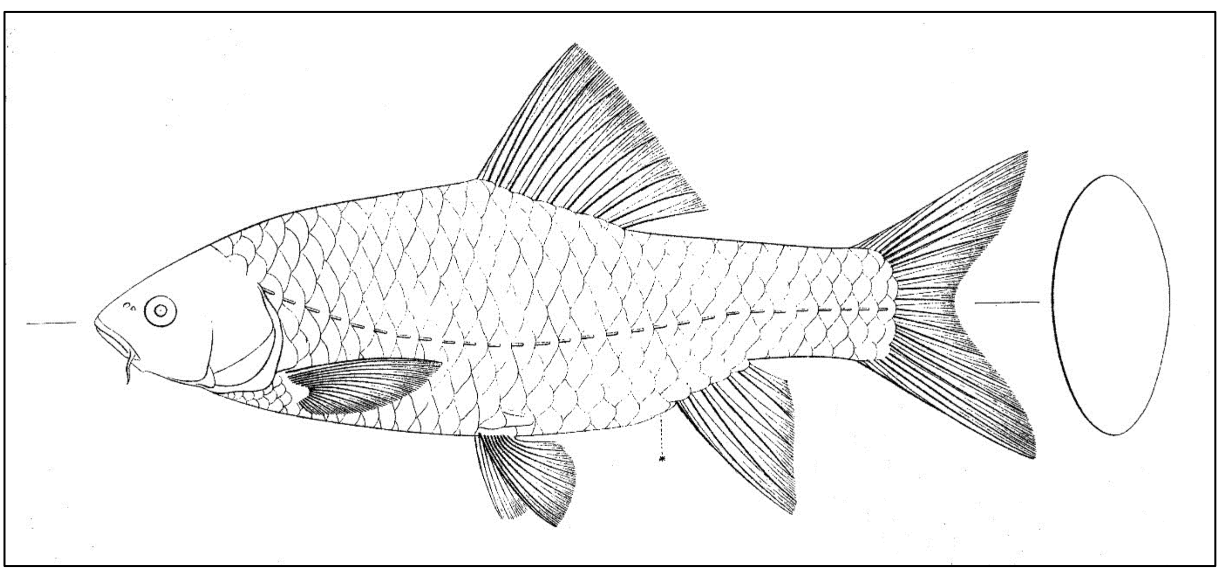


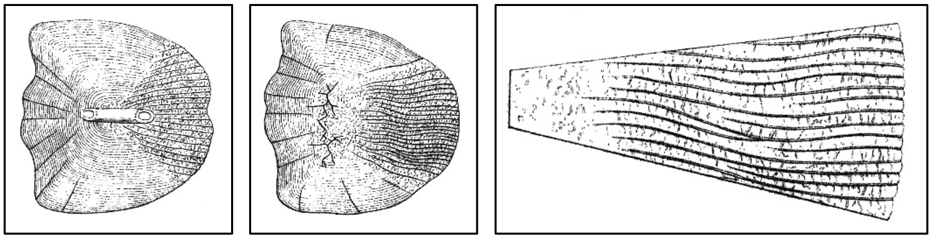
*Carasobarbus luteus*, 120.7 mm standard length,
ventral head, modified after Borkenhagen and Krupp (2013).

**Common names.** Hemri, hamri, himri (= reddish, Y. Keivany, pers. comm., 25 September 2018); lab matiki (= from lipstick, used by professional fishermen at Kermanshah in reference to red lips, J. Valiallahi, pers. comm., 2001), sangal or zangol (= blackish, used at Kermanshah, J. Valiallahi, pers. comm., 2001);.

[Binni, binni hamour, binni hamri, bunni himri (from humra or himri, red colour), beni asphar (meaning yellow son), beni hamra (meaning red or yellow son), binni shifatha (from shafata, thick-lipped), bartema (from baratim, thick lips), beni abjad or beni abjas for *Systomus albus* (meaning white son or from b-j-s, meaning causing to flow or gush out), hamra, hamria, himri, zuri (possibly a place name) (most of previous except white son from Mikaili and Shayegh (2011)), all in Arabic; Bizir, Devsor (= redmouth, a local name in eastern Turkey) and Sangal, all in Turkish (Kaya *et al*., 2016); golden barb, himri barbel, Mesopotamian himri, yellow barbel].

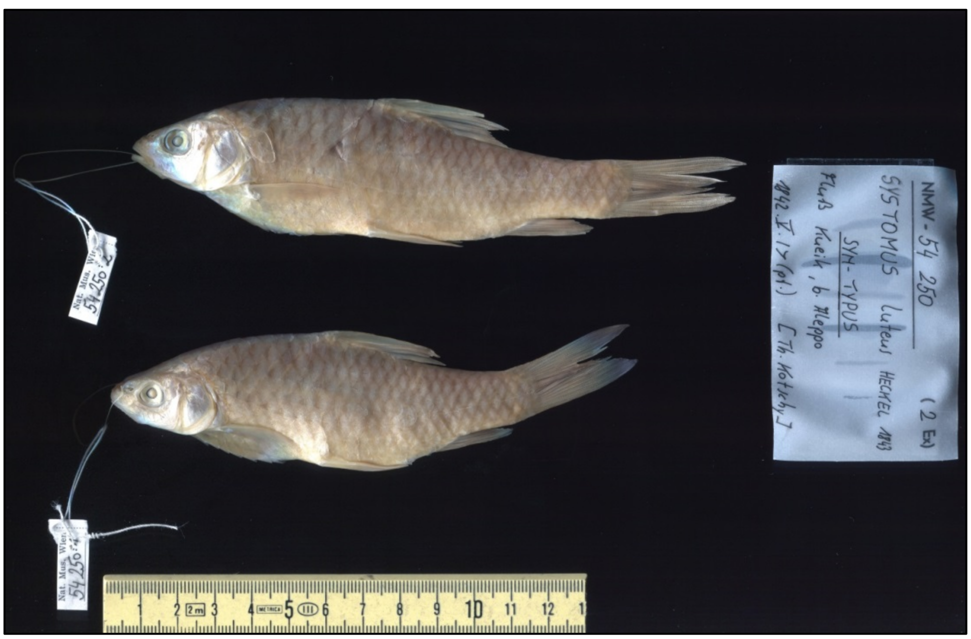
**Systematics.** Heckel (1843b) gave localities for the types of *Systomus luteus* as "Orontes", and "Tigris", and in the next sentence at "Aleppo" and "Mossul". Two syntypes were examined in the Naturhistorisches Museum Wien under NMW 54250 (but see below). Krupp (1985c) recorded a 301 mm standard length syntype from Aleppo formerly in the Naturhistorisches Museum Wien, now in the Senckenberg Museum Frankfurt as SMF 6784. Eschmeyer *et al*. (1996) listed the following syntypes:- NMW 10827 (1 fish), NMW 54247 (2), NMW 54248 (1), NMW 54249 (1), NMW 54250 (2), NMW 54253 (2), NMW 54254 (3), NMW 54255 (2), NMW 80043 (2) and possibly two syntypes in the Rijksmuseum van Natuurlijke Historie, Leiden (RMNH 2463, formerly NMW) as well as the syntype in Frankfurt. The catalogue in Vienna seems to list five specimens but this part of the catalogue is overwritten and difficult to interpret. Borkenhagen and Krupp (2013) gave the lectotype as NMW 54253 (211 mm standard length), the smaller of two specimens in this collection as the larger is atypical, having 11 dorsal fin branched rays and two pairs of barbels. This established the type locality as the Tigris at Mosul (Borkenhagen, 2017b). The *Catalog of Fishes* (downloaded 31 March 2018) gave the types as lectotype NMW 54253:2 and paralectotypes NMW 10827 (1), 54247-49 (2, 1, 1), 54250 (2), 54253-55 (1, 3, 2), 80043 (2), possibly RMNH 2463 (2), and SMF 6784.





*Systomus luteus*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

*Systomus luteus*, lectotype, NMW 54253:2, after Borkenhagen and Krupp (2103).




*Systomus luteus*, syntypes, NMW 54250, Naturhistorisches Museum, Wien.


*Systomus luteus*, syntypes, NMW 54250, Naturhistorisches Museum, Wien.

*Systomus albus* Heckel, 1843 from the “Tigris” and “Orontes” and *Systomus albus* var. *alpina* Heckel, 1847 are synonyms.

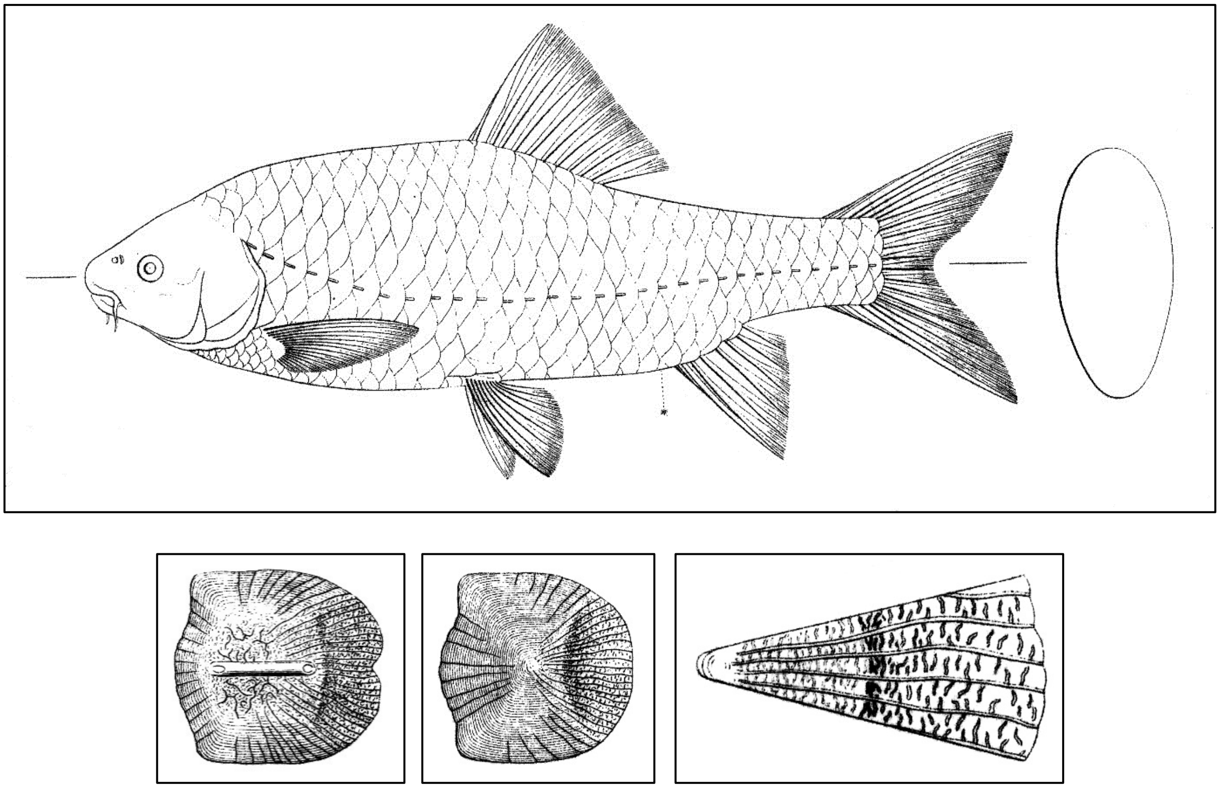
*Systomus albus* var. *alpina* was described from the “Flusse Kara-Agatsch und den Alpenseen Pire-San und Deria Kaserun” (= Qarah Aqaj River and Lake Parishan, Fars; Pire-San being Parishan and Deria Kaserun being Lake Kazerun, another name for Lake Parishan or Famur) (Heckel, 1847b). Krupp (1985c) recorded four syntypes of *alpina* from Shiraz (*sic*), Th. Kotschy as NMW 53679 (2) and NMW 53681 (2). NMW 53678 (5, 27.6-60.8 mm standard length), NMW 53679 (2, 63.8-70.5 mm standard length), and NMW 53681 (2, 79.6-93.3 mm standard length) are from the “Kara Agatsch bei Schiraz”; and NMW 53682 (2, 201.7-203.7 mm standard length) are from the “Alpenseen Pire-san und Deria Kaserun”: all are possibly syntypes of *Systomus albus* var. *alpina* although the catalogue in Vienna listed five fish under this name in one column and four fish in smaller writing in the adjacent column. The card index in 1997 listed syntypes under NMW 53678 (5), 53679 (2), 53681 (2) and 53682 (2, one of which is the lectotype). Eschmeyer *et al*. (1996) listed two fish in the Rijksmuseum van Natuurlijke Historie, Leiden (RMNH 2464) as possible former NMW types of this taxon. The *Catalog of Fishes* (downloaded 31 March 2018) gave the types as NMW 53678-79 (5, 2), 53681-82 (2, 2) and possibly RMNH 2464. B. Riedel (pers. comm., 11 April 2019) also listed NMW 94673 as a syntype (dry bone, *sic*, probably a dried or stuffed specimen in this case).


*Systomus albus* var. *alpina*, syntypes, NMW 53679, Naturhistorisches Museum, Wien.


*Systomus albus* var. *alpina*, syntypes, NMW 53679, Naturhistorisches Museum, Wien.

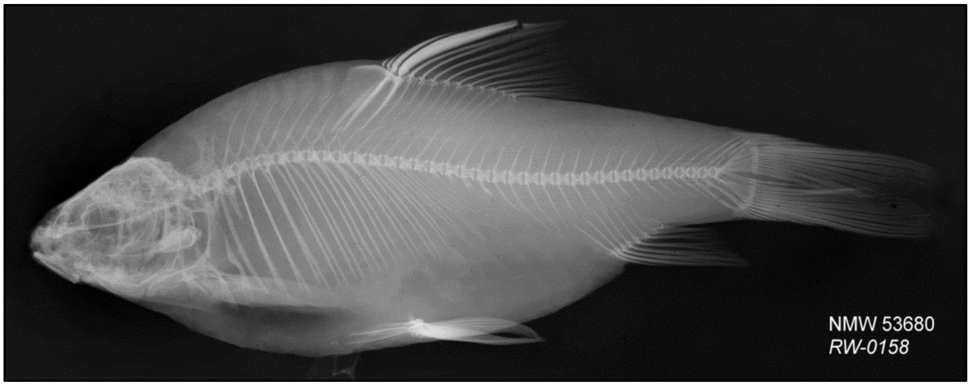
A dried specimen of *Systomus albus* from Mosul collected by Th. Kotschy may be a syntype (NMW 59485). Eschmeyer *et al*. (1996) gave the syntypes of this species as NMW 53674 (1), NMW 53675 (1), NMW 53676 (1), NMW 53677 (1), NMW 53680 (1), NMW 91400 (1, dry) and SMF 812 (1). Krupp (1985c) recorded the syntype of *albus* in the Senckenberg Museum Frankfurt under SMF 812 as being 84 mm standard length. The Vienna catalogue listed four fish under *Systomus albus* but the card index in 1997 listed the same NMW fish as Eschmeyer *et al*. (1996) as above with NMW 53680 as lectotype. The Ichthyology Type Database, NMW (downloaded 9 July 2016) gave the length of the latter as

159 mm standard length. B. Riedel (pers. comm., 11 April 2019) also listed NMW 94670 as a syntype (dry bone, *sic*, a dried or stuffed specimen in this case).



*Systomus albus*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Systomus albus*, syntype, NMW 53680, Naturhistorisches Museum, Wien.



*Systomus albus*, syntype, NMW 53680, Naturhistorisches Museum, Wien.

*Barbus parieschanica* Wossughi, Khoshzahmat and Etemadfar, 1982 is presumably also from Lake Parishan judging by the name and is a synonym (note that the species name is first spelt *parschanica* on page 23 in the abstract in Farsi and on page 44 in the English abstract but in the text species description (page 34) and in the table (page 37) it appears as *parieschanica*, and this is presumably the intended correct spelling). Coad (1995a) fixed *parieschanica* as the correct spelling as first revisor (Borkenhagen, 2017b). The species locality in the text is "Noorabad of Mamasany". The *Catalog of Fishes* (downloaded 12 April 2018) gave the date for this publication as 1983 although the paper has 1982 on the title page.

Günther (1874) placed this species in *Barynotus* Günther, 1868, a genus with the type species from West Africa. *Barynotus* is preoccupied in Coleoptera and was replaced by *Barbellion* Whitley, 1931 (Eschmeyer, 1990) and is now placed in *Labeobarbus* Rüppell, 1835 (*Catalog of Fishes*, downloaded 12 April 2018). Most authors placed the species in *Barbus*, although Karaman (1971) erected a new genus for it, *Carasobarbus*. Krupp (1985c) also synonymised *Carasobarbus* with *Barbus*. Bănărescu (1997) and Ekmekçi and Banarescu (1998) recognised *Carasobarbus* as a valid genus however. Borkenhagen *et al*. (2011) recognised *C. luteus* as a single, generalist species tolerating a wide variety of habitats.

Specimens from Fars collected by me show differences in body form from those in Khuzestan and this should be investigated.

Parmaksız and Eskici (2018) detailed the genetic variation in four populations in the Euphrates and Tigris rivers of Turkey using the mtDNA COI locus and Parmaksız (2021) determined genetic variation using mtDNA cyt *b* sequences in five populations from the Euphrates and Tigris rivers of Turkey.

**Key characters.** This species is characterised by a relatively low scale count (23-41 in the lateral line, often 33 or less), typically 12 scales around the caudal peduncle), smooth last dorsal fin unbranched ray, one (more rarely two) pairs of barbels, 10 branched dorsal and 6 anal fin branched rays, and the last unbranched ray of the dorsal fin about as long as the head or slightly shorter.

**Morphology.** The body is rounded, stocky and moderately deep. It is deepest midway between the dorsal fin and the head. The predorsal profile is gently convex to straight and sometimes has an inflection at the occiput and a steep fall to the snout. The caudal peduncle is compressed and deep. The snout tip is rounded and the eye is in the anterior half of the head. The mouth is terminal to subterminal, oblique and reaching back to the nostril level. The upper lip is moderately thick, thickest at the tip in large fish, more uniform in size in small fish, thinning laterally and then thicker at the mouth corner. The lower lip is thicker than the upper

lip. There is one pair of short and thin barbels at the corner in most descriptions. The barbel extends back to the eye at a maximum or falls short, although in some young fish it extends back to the mid-eye while in others it only reaches the anterior eye margin. Number and frequencies for 130 fish are two barbels (47 or 36.2%), three barbels with left anterior present (7 or 5.4%), three barbels with right anterior present (5 or 3.8%), or four barbels (71 or 54.6%). However, this sample is 112 fish or 86.2% from Fars and Hormozgan. Fish from these provinces, at such localities as the lower Mond River and the Sar Khun oasis north of Bandar-e Abbas consistently have a high frequency of four barbels (58.9%) and, with three barbel counts included, 68.8%, more than fish from the Tigris River basin. Even the 18 fish from the Tigris River basin had five fish with four barbels so, at least in the eastern part of this species range, fish with four barbels are not rare. Borkenhagen and Krupp (2013) examined 421 fish and found 365 (86.7%) with one pair of barbels, nine (2.1%) with three barbels and 47 (11.2%) with two pairs. They also commented on the Sar Khun oasis fish (Naband River basin) noting the two pairs of barbels, the last dorsal fin unbranched ray (spine) being weak and considerably shorter than the head, a longer head and less deep body, and the dorsal and ventral fins more posterior. The dorsal fin spine elsewhere is strong and lacks denticles. The dorsal fin margin is concave or straight and the fin origin is over the pelvic fin origin or anterior in young. The depressed dorsal fin falls short of the anal fin origin level or almost reaches it, and reaches past it in young fish. The caudal fin fork is moderate to deep and the lobes are rounded to pointed. The anal fin margin is emarginate to rounded and the fin does not reach back to the caudal fin base except in young fish. The pelvic fin is rounded and is remote from the anal fin. The pectoral fin is rounded and does not extend back to the pelvic fin origin, or almost to it in young fish.

Body form varies with habitat (Ali, 1982a), there being lake and river forms as with many other cyprinoid species. Larger fish, over 10.0 cm standard length, develop a nuchal hump. Fish from the Hormuz, Lake Maharlu and Persis basins have the last dorsal fin unbranched ray shorter and less well ossified than Tigris-Euphrates basin fish. The mouth is wider and the body is less deep.

Dorsal fin with 4 unbranched rays followed by 8-11, usually and modally 10, branched rays. Borkenhagen and Krupp (2013) gave frequencies of 8(1), 9(23), 10(411) or 11(6). The last dorsal fin unbranched ray is smooth, thickened, sharp-edged and spine-like with only the tip flexible. This ray is about as long as the head or slightly shorter. Anal fin with 3 unbranched rays followed by 5-7, usually and modally 6, branched rays, pectoral fin branched rays 13-17, and pelvic fin branched rays 7-9, usually 8. Lateral line scales 23-41, usualy 33 or less (Borkenhagen and Krupp (2013) and Borkenhagen (2017b) gave a range of 25-33). Typically, there are 12 scales around the caudal peduncle. There is a pelvic axillary scale. Scale shape is squarish, with the posterior margin shallowly to deeply rounded, the dorsal and ventral margins straight to slightly rounded, and the anterior scale margin wavy or centrally rounded with indentations above and below. There are moderate to many anterior field radii and many posterior field radii and occasionally a few lateral radii. The focus is central to subcentral anterior and this area of the scale may be broken up into lines. The exposed part of the scale is coarse. The concealed part of the scale has numerous fine circuli. Total gill rakers number 7-16, reaching the adjacent raker when appressed, sometimes forked at the tip and with spinules on the anterior side. Pharyngeal teeth are usually 2,3,5-5,3,2, with the anterior 2-3 main row teeth rounded and heavier than the posterior teeth. Variants are 2,3,4-5,3,2, 2,3,5-4,3,2, 2,3,5-5,3,3 and 1,3,5-5,3,2 (Borkenhagen, 2005; Borkenhagen and Krupp, 2013). Posterior teeth are

hooked at the tip and the grinding surface below the tip is irregular with a protuberant knob which may be striated. The gut is elongate with both posterior and anterior loops. Total vertebrae number 36-40.

Abdullah (2016) described the osteology of the premaxilla, maxilla, lower jaw and operculum. Jawad *et al*. (2017) gave details on the vertebrae.

Meristic values for Iranian specimens are:- dorsal fin branched rays 9(7), 10(102) or 11(7), anal fin branched rays 5(3) or 6(114), pectoral fin branched rays 14(12), 15(44), 16(48) or 17(13), pelvic fin branched rays 7(9), 8(107) or 9(1), lateral line scales 23(2), 24(10), 25(20), 26(22), 27(28), 28(16), 29(14), 30(4) or 31(1), total gill rakers 8(6), 9(24), 10(40), 11(28), 12(12), 13(3) or 14(2), pharyngeal teeth 2,3,5-5,3,2(19), 2,3,4-5,3,2(4) or 2,3,5-4,3,2(2), and total vertebrae 36(8), 37(53), 38(70), 39(25) or 40(1). A syntype of *S. luteus*, NMW 54250, has 40 vertebrae (and the other syntype has fusions). The syntype of *S. albus*, NMW 53680, has 39 vertebrae and the syntypes of *S. albus* var. *alpina*, NMW 53679, both have 38 vertebrae.

**Sexual dimorphism.** A fish from the lower Mond River (128.5 mm standard length, no capture date, CMNFI 2008-0135) has fine tubercles on the upper flank scales as well as the head and fin rays. Fin tubercles follow the rays of the dorsal, anal, caudal, pectoral and pelvic fins, branching with the ray and strongest on the anal fin. Ali (1982a) reported no sexual dimorphism for Iraqi fish.

**Colour.** The back and upper flank is dark brown, greenish black or grey-green fading to a whitish or silvery belly all overlain by an orange to yellowish tinge. On the upper flank, scale bases are black-brown with a light blue-grey margin. There is a dark stripe along the mid-line of the back and a dark mid-lateral stripe. Fins are greyish to lime-green, reddish-yellow or orange, becoming blackish distally. The pectoral and pelvic fins tend to be more orange than the anal and caudal fins which are more a faint lime-green. The lips are orange or reddish. The eye rim is yellow-green and the iris is orange. The peritoneum is black. Small fish have a collection of melanophores at the mid-base of the caudal fin forming a spot-like structure. Males become reddish-brown on the anterior body and greenish at the caudal peduncle during spawning (Borkenhagen and Krupp, 2013)

The fish described by Heckel (1847b) as *Systomus albus* var. *alpina* were also painted live and had a lead-grey body, light brown at the head and reddish-white on the belly. Each scale was black-brown at the base and light blue-grey at the margin, particularly on the upper flank. All fins were blackish and the eyes orange-red.

**Size.** Attains 38.0 cm calculated maximum length and 501 g (Ahmed, 1982) or 750 g (Borkenhagen, 2005). Heckel (1843b) gave 17 Zoll for *Systomus albus* (= 44.8 cm). Mohamed (2014) found fish from the Al-Huwaizeh Marsh, Iraq attained 35.0 cm total length. Biria *et al*. (2014) found a maximum total length of 25.2 cm (a female) for 384 fish from the Karun River (Aqili Desert, Shushtar), Javaheri Baboli and Sayahi (2014) recorded fish up to 29.0 cm from the Karkheh River, and Eydizadeh *et al*. (2013) found fish up to 36.2 cm from the Hawr al Azim. A large specimen from Barm-e Shur near Shiraz was 43.7 cm total length and 36.0 cm standard length (see below in **Habitat**).

**Distribution.** This species is found in the Orontes and Quwayq rivers (the former with a few old records (possibly erroneous) and the latter probably extirpated according to Borkenhagen and Krupp (2013)) and the Tigris-Euphrates basin of Turkey, Syria and Iraq, and southern basins of Iran. In Iran, it is found in the Hormuz, Kor River (possibly, see below), Lake Maharlu, Persis and the Tigris River basins, including a wide variety of marshes, streams,

springs, qanats, ponds and channels in these basins not all named here but referenced in **Sources**. In the Hormuz basin in the Galehgah (= Galu Gah), Kul, Naband, Rostam, Shur and Tas rivers and Golabi Spring; the Lake Maharlu basin at Ab-e Paravan, Baba Haji, Barm-e Shur and Pol-e Berengie; the Persis basin including the Dadina Spring and Lake Parishan and the Alamarvdasht, Dalaki, Dasht-e Palang, Fahlian, Helleh, Jeleh, Mond (and its estuary), Qarah Aqaj, Ras, Rudbal (= Rudbar), Shapur, Shirin-Khaeiz, Shur, Simakan, Tang-e Shiv, Tankab and Zohreh rivers; and the Tigris River basin including the Alvand, Arvand, Balarud, Dasht-e Palang, Dez, Dinvar, Gamasiab, Gavi, Godarkhosh, Gangir, Jagiran, Jarrahi, Kahnak, Karkheh, Karun, Kupal, Mah, Marun, Pol-e Bala, Qareh Su, Raz Avar, Shate-Neisan, Nahr-e Shavor, Shur, Simareh, Talkhab and Zard rivers, the Hawr al Azim and Shadegan marshes, sarabs near Kermanshah, and the Dez and Karkheh dams (Wossughi, 1978; Bianco and Banarescu, 1982; Gh. Izadpanahi, pers. comm., 1995; M. Rabbaniha, pers. comm., 1995; Abdoli, 2000; Eskandari *et al*., 2007; Biokani *et al*., 2011; Teimori *et al*., 2010; Zareian *et al*., 2012; Biukani *et al*., 2013; Borkenhagen and Krupp, 2013; Javaheri Baboli *et al*., 2013; Maghsoudloo *et al*., 2013; Pirani *et al*., 2013; Banaee and Naderi, 2014; Dadashi *et al*., 2014; Golchin Manshadi *et al*., 2014; Khoshnood, 2014; Sadeghi Limanjoob *et al*., 2014; Esmaeili *et al*., 2015; Taghavi Niya and Velayatzadeh, 2015; Momtazan *et al*., 2016; Pazira *et al*., 2016; Gholamifard, 2017; Fatemi *et al*., 2019; Khamees *et al*., 2019; Jouladeh-Roudbar *et al*., 2020).

The record from the Kor River basin (Abdoli, 2000) needs confirmation with specimens, and could be an introduction, as none were collected in this basin in the 1970s by me. Zamanpoore *et al*. (2016), Zamanpoore and Yaripour (2017) and Paighambari *et al*. (2020) also recorded it from the Dorudzan Dam on the Kor River which has exotic species.

**Zoogeography.** Karaman (1971) considered that the closest relatives of this species were to be found in India and southern Asia. Borkenhagen and Krupp (2013) stated this species to be closely related to *C*. *apoensis* (Banister and Clarke, 1977) of southwestern Saudi Arabia.

**Habitat.** This species is found in rivers, streams, lakes, dams, lagoons, ponds, marshes, springs, qanats and brackish environments. van den Eelaart (1954) reported that this species in Iraq was a resident in still water and the slower sections of rivers and was the main fish in canals. In summer it went to the deeper basins of marshes and remained in the shade of plants. It tolerated warm water but did not go into open waters. Al-Hassan and Muhsin (1986) recorded this species from the Khor al Zubair in southern Iraq where annual temperature range was 12-30°C and annual salinity change was 28-47‰. The fish appeared unaffected by these conditions while the stinging catfish *Heteropneustes fossilis* (Heteropneustidae)) was moribund. Mohamed *et al*. (1993) reported *Barbus* (= *Carasobarbus*) *luteus* from 2 km southward of Fao, Iraq in a pure marine habitat (temperature 13-35°C and salinity 30-47‰). The fish were caught in April which is the flood season. It has been caught at a water temperature of 30°C on 24 November 1976 in a spring near Farrashband, Fars (CMNFI 1979-0129) and at 31°C in Lake Parishan on 4 June 1977 (CMNFI 1979-0240 - air temperature was 43°C). A specimen 43.7 cm total length was caught gasping at the surface of Barm-e Shur near Shiraz (CMNFI 1979-0076) when amphibious vehicles stirred up the mud bottom of the pool.

Habitat of *Carasobarbus luteus*, CMNFI 1979-0304,
Fars, Lake Parishan, 24 October 1977, Brian W. Coad.

**Age and growth.** Esmaeili and Ebrahimi (2006) gave a significant length-weight relationship based on 34 Iranian fish measuring 3.2-16.8 cm standard length. The *b* value was 3.036. Eydizadeh *et al*. (2013, 2014) studied 466 fish, 11.8-36.2 cm total length, in the Hawr al Azim Wetland in Khuzestan and found a maximum weight 416 g, a sex ratio of 0.51:1 in favour of females with no significant difference between months, a mean size at first sexual maturity of 21.0 cm, a length-weight relationship of $W = 0.0018TL^{3.18}$ showing isometric growth, $L_\infty = 37.5$ cm, $K = 0.67y^{-1}$, $t_0 = -0.16$, natural mortality (M) = 1.22, F = 0.46, total mortality (Z) = 1.66, exploitation rate (E) = 0.28, relative yield per recruitment (Y'/R) = 0.02, relative biomass per recruitment (B'/R) = 0.21, and $E_{max} = 0.59$. The stock was not overfished. Javaheri Baboli *et al*. (2013) found 210 fish in the Karkheh River had a maximum condition factor for males in February and for females in October with the lowest in January and July respectively. Fish attained $6^+$ years of age. Biria *al*. (2014) found length-weight relationships for 384 fish, 11.8-25.2 cm total length, from the Karun River (Aqili Desert, Shushtar) of W =

$0.00001TL^{3.02}$ for females, 11.9-25.2 cm total length, and $0.00001TL^{2.99}$ for males, 11.8-22.6 cm total length, indicating isometric growth. Esmaeili *et al*. (2014) gave a *b* value for 47 fish from the Persian Gulf (Persis) basin, 5.06-10.9 cm total length, as 3.41; for 42 more fish from the Persian Gulf basin, 3.93-11.6 cm total length, as 3.22; for 37 fish from the Hormuz basin, 3.61-21.2 cm total length, as 3.05; and for 10 fish from the Lake Maharlu basin, 9.34-18.5 cm total length, as 3.06, and totally as 3.18. Javaheri Baboli and Sayahi (2014) examined 210 fish, 7.5-29.0 cm total length, from the Karkheh River and found a male:female ratio of 0.83:1, females attained $6^+$ years and males $5^+$ years, the length-weight relationship was $W = 0.0152L^{2.9293}$ for males and $W = 0.0185L^{2.857}$ for females, and von Bertalanffy growth parameters were $L_t = 31.78(1\text{-}e^{-0.16(t + 0.35)})$ for males and $L_t = 28.34(1\text{-}e^{-0.23(t + 0.44)})$ for females. Khoramian *et al*. (2014c) gave a total length and weight relationship for 104 Karkheh River fish as LogW = -1.002 + 3.09LogL indicating isometric growth. The condition factor was 0.82. Ghorbani *et al*. (2018) studied the population dynamics of 276 males (11.0-22.2 cm mean total length range) and 1,332 females (9.5-28.0 cm) from the Shadegan Wetland. The length-weight relationship was $W = 0.013L^{3.0124}$ for males and $W = 0.0136L^{3.0117}$ for females, showing an isometric growth pattern. The condition factor (K) was calculated to be 1.308 and 1.368 for the males and females, respectively, showing significant differences with males significantly lower than females and maximum and minimum values observed in winter and spring. Growth indices including $L_\infty$, growth coefficient and $t_0$ were 305 and 301 mm, 0.67 and 0.55 per year and 0.23 and 0.29 for males and females, respectively. Natural mortality, fishing mortality, total mortality, Munro Φ' and coefficient of exploitation were 1.22 and 1.02 per year, 1.61 and 1.45 per year, 2.83 and 2.47 per year, 2.79 and 2.72, and 0.57 and 0.59, respectively for males and females. Paighambari *et al*. (2020) gave a *b* value of 3.12 for 20 fish, 18.5-32.6 cm total length, from the Dorudzan Dam, Fars. Valikhani *et al*. (2020) combined fish from the Shadegan Wetland and the Dez and Karkheh rivers and reported a *b* value of 2.93 (isometric growth) and a condition factor of 2.5 for 328 fish, 3.3-11.9 cm total length.

Ahmed (1982) studied a population in Tharthar Reservoir about 65 km northwest of Baghdad and found 7 age groups. This study had the fastest growth of Iraqi populations. Barak and Mohamed (1983) found 6 age groups for fish from the Garma Marshes, Iraq. Ahmed *et al*. (1984) studied the reproductive cycle of this species in the Hawr al Hammar in southern Iraq near Basrah. Maturity was attained at a minimum of 11.2 cm for females and 12.2 cm for males, at age $1^+$. The largest fish were 26.0 cm and age 6. Biro *et al*. (1988) found fish up to age group $8^+$ in the Diyala River, Iraq. Khalaf *et al*. (1988) worked on a population in a flooded gravel pit about 50 km north of Baghdad in Iraq and found fish up to age group $7^+$. Growth was greatest in the first year (67 mm) and averaged only 22.5 mm in the following years. Growth was slow in consequence of high salinity (3-6%, *sic*) and poor food resources. Mohamed *et al*. (1993) reported fish up to 7 years of age in a marine setting in Iraq, Epler *et al*. (1996) up to $5^+$ years in fresh and salty Iraqi lakes. Mohamed (2014) gave a length-weight relationship for fish from the Al-Huwaizeh Marsh, Iraq of $W = 0.0104L^{3.084}$ and a relative condition factor of 0.881 for a mean length of 15.4 cm to 1.165 for length 30.5 cm, with an overall mean of 1.002. Total annual mortality ($Z$) was 0.957 for fish 17.5 to 34.5 cm, natural mortality ($M$) was 0.336, fishing mortality ($F$) was 0.621, and exploitation rate ($E$) was 0.649. Mohamed *et al*. (2015) found fish in the east Hammar Marsh, Iraq represented about 2.2% of the total fish catch, fish 12-19 cm represented 72.3% of this species caught, length-weight relationship was $W = 0.0075L^{3.2245}$ showing allometric growth, 6 age groups were present, asymptotic length ($L_\infty$) was 37 cm, growth coefficient (K) was 0.26, and growth was considered as fairly good. Al-

Jubouri (2019) examined 551 fish, total length 8-30 cm, from the Al-Diwaniyah River, Iraq and found this species comprised 9.23% of the fish assemblage, $W = 0.0133L^{3.047}$ showing allometric growth, the sex ratio differed significantly from 1:1 in favour of females, mean values of relative condition factor for small fish, males and females were 0.79, 0.95 and 0.96, respectively, seven age groups were recognized with lengths 10.5, 16.4, 19.9, 23.3, 25.9, 27.9 and 29.3 cm, length group 19 cm dominated, and von Bertalanffy growth constants were $L_\infty$ = 35 cm, K = 0.280 and $t_o$ = -0.101. The growth performance index (Φ) was 2.53. The total (Z), natural (M) and fishing (F) mortality rates were assessed by applying the length cohort analysis and were 0.964, 0.347 and 0.617, respectively. The exploitation rate (E) estimate was 0.640, exceeding the optimal level of exploitation (E = 0.5), so this fish stock was overexploited. The following report was presumably based, at least in part, on this thesis. Abdullah and Mohamed (2019) reported on fish from the Al-Diwaniya River where this species constituted about 29.8% of the catch. The length-weight relationship for fish 8-30 cm total length was $W = 0.0133L^{3.047}$, the mean relative condition factor was 0.79 for small fish, 0.95 for males and 0.96 for females, fish lengths were 10.5, 16.4, 19.9, 23.2, 25.9, 27.9 and 29.3 cm at the end of 1-7 years respectively, the male:female sex ratio was 1:1.5, the growth model was $L_t = 35(1-e^{-0.26(t-0.489)})$, and the growth performance index was 2.5.

Al Hazzaa and Hussein (2007) described larval development and growth in the laboratory using fish from a Syrian hatchery.

Gökçek and Akyurt (2008) found fish up to 9 years of age in the Turkish Orontes River and gave growth parameters for this population. Bilici *et al*. (2016) found fish up to age 9 in the Tigris River of Turkey and Bilici *et al*. (2017) gave a length-weight relationship of log W = -4.7314 + 3.0113 log fork length for females and log W = -4.7631 + 3.0263 log fork length for males, von Bertalanffy growth equations were $L_t = 40.09[1-e^{-0.087036(t+1.55004)}]$ for females and were $L_t = 38.14[1-e^{-0.080056(t+2.34838)}]$ for males, the somatic condition was 1.9667 for females and 1.9967 for males.

**Food.** Khoshzahmat *et al*. (1981) found that this species did not eat molluscs in Lake Parishan (= Famur), near Kazerun in Iran and assumed its diet was aquatic plants.

Barak and Mohamed (1982) studied food habits in the Garma Marshes, near Basrah, Iraq and found this fish to contain principally aquatic plants, the broken and fragmented leaves and stems of *Vallisneria* in particular. Diatoms and other algae as well as shrimps, chironomid larvae, gastropods and cladocerans were important foods. Invertebrates were about eight times more important in fish smaller than 30 cm than in larger fish. Plant parts were more important, almost twice as much, in larger fish than smaller. Naama and Muhsen (1986) examined feeding periodicities in this species in the Hawr al Hammar, Iraq. Food was mainly detritus, aquatic plants and algae taken throughout the night and day. Mohamed *et al*. (1993) reported plant remains to be dominant and fish eggs in lesser quantities in a marine setting in Iraq. Epler *et al*. (1996) found plants to dominate in fish from fresh and salty Iraqi lakes, although not to the same extent as in *Barbus* (= *Mesopotamichthys*) *sharpeyi* where 95.7-100% of the diet was plants. Tendipedids, worms, detritus and fish were also found in *C. luteus*. Mohamed (2014) found algae, diatoms and higher plants in order of importance as food items, but with insects replacing the latter in spring and winter, in the Al-Huwaizeh Marsh, Iraq. Plants formed 79.2% of the diet but crustaceans and snails also formed a minor part of the diet. Mohamed *et al*. (2015) showed fish in the east Hammar Marsh, Iraq ate aquatic plants (22.3%), algae (19.8%), insects (13.8%), snails (12.8%) and isopods (11.4%). Mohamed and Abood (2018) found this species was a generalised feeder in the Shatt al Arab, Iraq and the diet was primarily algae

(24.3%), aquatic insects (23.0%), macrophytes (21.6%), detritus (10.9%), diatoms (9.9%) and snails (8.0%). The diet of exotic *Carassius auratus* was close to that of *C. luteus* and these species were in competition for food items in the Shatt al Arab River (Mohamed and Abood, 2018, 2021). Al-Jubouri (2019) found fish from the Al-Diwaniya River fed mainly on aquatic plants (41.4%), algae (39.1%), snails (11.0%), and aquatic insects (8.7%). The highest feeding overlap (0.93) was found between *Mesopotamichthys sharpeyi* and *C. luteus*, and between *C. luteus* and *Arabibarbus grypus* (0.90). The following report was presumably based, at least in part, on this thesis.
Abdullah and Mohamed (2019) reported on fish from the Al-Diwaniya River, Iraq and concluded this species was an herbivore feeding mainly on aquatic plants (40.3%), algae (39.1%), snails (11.0%) and aquatic insects (8.5%).

**Reproduction.** Iranian fish have well-developed eggs in May (samples examined by me). Javaheri Baboli *et al*. (2013) found fish in the Karkheh River had the highest gonadosomatic indices in April for both sexes and spawning occurred from April to May. Banaee *et al*. (2014) found Marun River fish had a male:female sex ratio of 1:2.47, maximum gonadosomatic values in fish 2-6 years old were in April and May, reproductive activity started around the end of March and continued to early July, and the hepatosomatic index increased in April and May associated with vitellogenesis and vitellogenin synthesis verified by histology of ovarian tissue. Eydizadeh *et al*. (2014) found fish in the Hawr al Azim Wetland had maturity stages indicating spawning from April to July. Biria *et al*. (2017) examined fish from the Karun River and found an equal sex ratio, maximum egg diameter in February, mean absolute fecundity of 5,754 eggs, average relative fecundity of 53.3 eggs/g, and spawning, possibly asynchronous, in February and October. Ershad Langroudi and Tagheipour Kouhbane (2017) found fish from the Aghli Plain in Khuzestan had an average absolute fecundity of 5,754 eggs and a relative fecundity of 53.3 eggs/g. The condition factor average during a year of sampling was 1.172. Ghorbani *et al*. (2018) in their Shadegan Wetland study found that this species spawned in April-July with a long spawning period and a sexual dormant period in autumn to early winter. Mean length at maturation was 16.1 and 17.4 cm and the weight of mature fish was 60 and 80 g, for males and females respectively.

Bhatti and Al-Daham (1978) and Al-Daham and Bhatti (1979) reported a spawning season of May-July (peak June-July) for a lower Euphrates River, Iraq population, perhaps as a result of cooler temperatures outside the shallow marshes where warmer temperatures caused an earlier development of gonads. Spawning in the Hawr al Hammar, Iraq started in April and after July no fish were found in a partially spent phase. Eggs were yellow to orange in colour and testes white. The eggs attained 1.86 mm in diameter and numbered up to 38,433 for the oldest fish (Ahmed *et al*., 1984). Epler *et al*. (1996) reported spawning in June/July in freshwater Iraqi lakes, earlier in a saline lake. Mohamed *et al*. (2015) found fish in the east Hammar Marsh, Iraq had a highest gonadosomatic index in April for females (13.9) and March for males (7.74), showing a March to April spawning season. Al-Jubouri (2019) found fish from the Al-Diwaniya River, Iraq had the highest values for the gonadosomatic index for female and male fish at 13.7 and 7.8 in April. The following report was presumably based on this thesis. Abdullah and Mohamed (2019) reported fish from the Al-Diwaniya River had the highest gonadosomatic indices, 13.7 and 7.8, in April for females and males respectively when spawning was assumed to take place.

Al Hazzaza and Hussein (2003b) recorded sexually mature females were 23.2-27.5 cm standard length and 355-395 g for Syrian Euphrates fish while males were 21.8-26.5 cm and

110-413 g. Fertilised eggs, 1.1-1.18 mm, hatched after 64 degree-days.

Bilici *et al*. (2016) examined fish from the Turkish Tigris River and found the female:male sex ratio was 1:1.22, the reproduction period was between May and July, the water temperature at this period was between 21.4°C and 31°C, age at first maturity was 3 years for both males and females, the mean estimated fecundity was 5,843 (maximum 14,678) eggs, relative fecundity was up to 56.6 with a mean of 44.61 eggs/g, and maximum egg diameter was 1.61 mm.

**Parasites and predators.** Bykhovski (1949) described a new species of monogenetic trematode, *Dactylogyrus persis*, from this species in the Karkheh River, Iran. Ebrahimzadeh and Nabawi (1975) listed species in the nematode genus *Philometra*, the protozoan genera *Myxosoma* and *Trypanosoma*, the trematode genera *Dactylogyrus* and *Gyrodactylus* and the nematode species *Camallanus lacustris* as well as various unidentified cestodes, trematodes, acanthocephalans and hookworms, from this species in the Karun River. Jalali and Molnár (1990a) recorded two monogenean species, *Dactylogyrus* spp., from this species in the Dez River. Moghainemi and Abbasi (1992) recorded a wide range of parasites from this species in the Hawr al Azim in Khuzestan. Molnár and Jalali (1992) described a new species of monogenean, *Dogielius persicus*, from this species in the Dez and Karun rivers of Khuzestan. Gussev *et al*. (1993b) described a new species, *Dactylogyrus carassobarbi*, from this species in the Dez River, Khuzestan, the specific name being founded on a misspelling of the genus name *Carasobarbus*. Masoumian *et al*. (1994) described a new species of Myxosporea from the gills of this species in the Karun River, Khuzestan, namely *Myxobolus persicus*, and later (Masoumian *et al*., 1996b) another new species of Myxosporea, *Myxobolus nodulointestinalis*, in the gut lining of this species, also from rivers of southwestern Iran. Molnár *et al*. (1996) reported additional new species from this fish in Khuzestan, namely *Myxobolus iranicus* in the spleen and *Myxobolus mesopotamiae* in connective tissue of the caudal and pectoral fins. Molnár and Pazooki (1995) recorded philometrid nematodes from this species in the Karun River, and these were presumed to be a new species. González-Solís *et al*. (1997) reported Proleptinae larvae (Nematoda) from this species in the drainage of Lake Maharlu, Fars. The definitive host was a predatory fish, possibly the spiny eel *Mastacembelus mastacembelus*, not then recorded from this basin. Masoumian and Pazooki (1999b) listed *Myxobolus iranicus, M. karuni, M. mesopotamiae*, *M. nodulointestinalis*, *M. persicus* and *M. sharpeyi* from this species in various localities in Khuzestan. Jalali *et al*. (2005) summarised the occurrence of *Gyrodactylus* species in Iran and recorded *G.* sp. from Dez River fish. Farahnak *et al*. (2002) reported *Anisakis* sp. and Mortezaei *et al*. (2007) the nematode *Rhabdocona denudata* from this fish in Khuzestan, the latter in the Shadegan Marsh.

Mortezaei *et al*. (2000) recorded an infection rate of 1.6% with the worm *Bothriocephalus opsariichthydis* in Khuzestan marshes. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Argulus* sp., *Ergasilus* sp., *Ergasilus sieboldi* and *Lernaea* sp. on this species. Golchin Manshadi *et al*. (2012) and Golchin Manshadi (2018) found *Ichthyophthirius multifilis*, *Trichodina nigra*, *Myxobolus karuni*, *M. mulleri*, *M. pfeifferi*, *Dactylogyrus carassobarbi* and *Gyrodactylus* sp. in this species in Lake Parishan. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Neoechinorhynchus* sp. from fish in Khuzestan. Golchin Manshadi and Khaj (2016) compared haematological factors in fish from Lake Parishan infected with, or free from, *Contracaecum* sp. The amount of lymphocytes decreased by increasing infection while occurrence of monocytes, neutrophils and thrombocytes increased in severe infection. The average amount of haematocrit and red blood

cells in uninfected, mildly infected and severely infected fishes were different and decreasing while the average counts of white blood cells increased in uninfected, mildly infected and severely infected fishes. Golchin Manshadi (2017) reported *Dactylogyrus carasobarbi*, *Gyrodactylus* sp., *Trichodina* sp. and *Myxobolus* sp. from fish in Lake Parishan, Fars. Moumeni *et al*. (2020) recorded the zoonotics *Anisakis* spp., *Contracaecum* spp., *Philometra karunensis* and *Capillaria* spp. from this fish in Iran.

**Economic importance.** This species is an important food fish in southern Iraq and Iran and in the Tigris River of Turkey (Al-Daham and Bhatti, 1979; Ahmed, 1982; Bilici *et al*., 2017). Heckel (1847b) reported that they "reach a good size and are very tasty" in Lake Parishan, Fars.

Sharma (1980) reported that this species was the fourth most important at Basrah fish market in Iraq, accounting for 267,570 kg from October 1975 to June 1977. In the Al-Huwaizeh Marsh, Iraq, close to the Iranian border, this species comprised 29.4% of the total catch on average and as much as 72.7% in December, dominating for 6 months of the year (Mohamed, 2014).

Ershad Langroudi and Tagheipour Kouhbane (2017) found fish from the Aghli Plain in Khuzestan contained 15-24% protein, 1-22% fat, 60-84% water and 2-8% mineral compounds. The flesh was better than red meats and was more digestible, 89-96% in comparison with cow and chicken. Javaheri Baboli *et al*. (2020) described seasonal variations in the liver and muscle fatty acid composition. The most abundant saturated fatty acids in the liver and muscles were at their highest point in autumn and spring, respectively, and the total monounsaturated fatty acids were at their highest in autumn for liver and winter for muscle, for example.

In some parts of Southwest Asia, this species was regarded as "sacred", kept and bred in special pools where fishing was forbidden (Tortonese, 1934).

The eggs of this species are poisonous (Najafpour and Coad, 2002). A kebab made of about one-quarter of an ovary was eaten. Toxic effects were dizziness, abdominal pain, vomiting, diarrhoea, bitter taste, dryness of mouth, intense thirst, and faintness. One victim was hospitalised for two days and his stomach pumped while a second victim recovered after one day's rest.

This species has been caught on worm bait in the Dalaki River by A. Shiralipour (November 1976, CMNFI 1979-0125).

**Experimental studies.** Askary Sary *et al*. (2013a) found levels of lead and cadmium in muscle tissue of fish from the Shapur River were lower than international standards prohibiting consumption. Velayatzadeh *et al*. (2015) examined levels of cadmium, copper, lead and mercury in liver and muscle of farmed fish from the Karun River basin, finding the highest levels in the liver, levels for all but copper being higher at Ahvaz than downstream at Aghili, and only cadmium exceeded international standards. Momtazan *et al*. (2016) found mercury levels of 0.388 mg/kg in muscle of fish from the Marun River at Behbahan, below the limit set by international standards. Velayatzadeh (2019) found this freshwater species had the highest levels of selenium in market fish at Ahvaz with *Mesopotamichthys sharpeyi* the lowest (0.291 and 0.251 mg/kg respectively). Two other species, *Arabibarbus grypus* and *Luciobarbus xanthopterus*, fell within this narrow range. Farmed *Cyprinus carpio* had 0.189 mg/kg.

Al Hazzaza and Hussein (2003c) propagated this species in a Syrian fish farm. Common carp pituitary extract injections increased fecundity and spermatozoan motility increased in hypotonic solutions. Hatching rate was low (57%) despite 97.8-98.6% fertilisation success. Apparently, males emitted sounds to stimulate egg release by females.

**Conservation.** Vulnerable in Turkey (Fricke *et al.*, 2007). Listed as of Least Concern by the IUCN (2015). It is a common species in Iranian freshwaters but no detailed conservation assessment has been made. Parmakisz (2019) examined 108 fish from nine localities in the Kueik, Euphrates and Tigris rivers in Turkey and Iraq using mitochondrial D-loop sequences, the information obtained being useful to plan effective strategies for conservation and fishery stocking.

**Sources.** Type material:- *Systomus luteus* (NMW 54250) and *Systomus albus* var. *alpina* (NMW 53678, NMW 53679, NMW 53681 and NMW 53682).

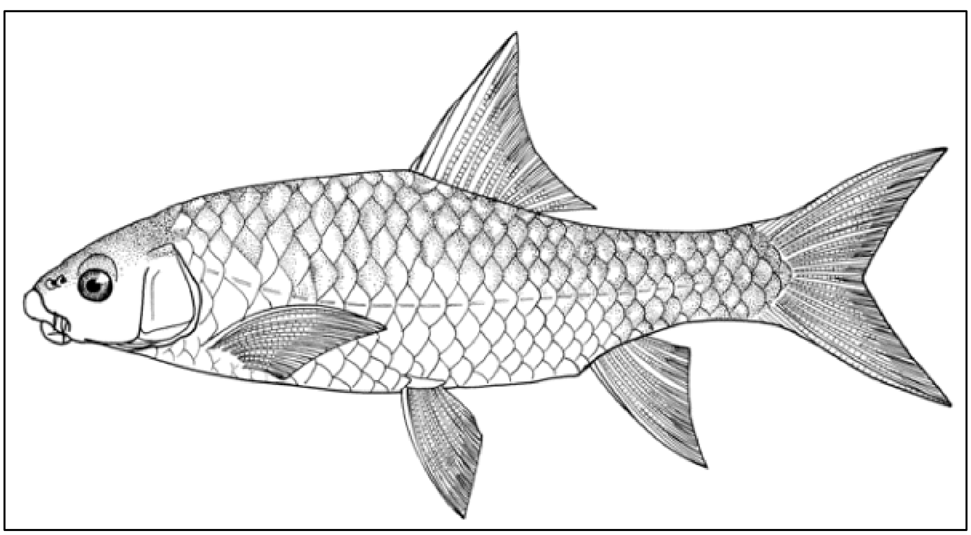
Iranian material:- CMNFI 1979-0023, 17, 58.3-161.4 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0024, 1, 61.5 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0026, 2, 36.5-64.5 mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0047, 1, 90.9 mm standard length, Fars, spring source of Ab-e Paravan marshes (ca. 29º34'N, ca. 52º42'E); CMNFI 1979-0076, 1, not kept, 36.0 mm standard length, Fars, Barm-e Shur (29º28'N, 52º41'30"E); CMNFI 1979-0087, 1, 212.1 mm standard length, Khuzestan, Karun River at Ahvaz (31º19'N, 48º42'E); CMNFI 1979-0125, 1, 113.2 mm standard length, Bushehr, Dalaki River near Dalaki (ca. 29º28'N, ca. 51º21'E); CMNFI 1979-0129, 26, 29.9-48.8 mm standard length, Fars, spring 2 km north of Farrashband (28º54'N, 52º04'E); CMNFI 1979-0154B, 3, 160.7-258.6 mm standard length, Fars, stream channels at Koorsiah (28º45'30"N, 54º24'E); CMNFI 1979-0155, 2, 71.8-100.6 mm standard length, Fars, spring at Gavanoo (28º47'N, 54º22'E); CMNFI 1979-0156, 6, 32.5-60.2 mm standard length, Fars, qanat in Rashidabad (28º47'N, 54º18'E); CMNFI 1979-0157, 1, 22.4 mm standard length, Fars, qanat stream at Hadiabad (28º52'N, 54º13'E); CMNFI 1979-0160, 2, 149.0-153.5 mm standard length, Fars, spring at Arteshkhadeh Pomp (29º09'N, 53º37'E); CMNFI 1979-0163, 1, 84.9 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0164, 6, 56.6-91.1 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0187, 31, 26.9-108.6 mm standard length, Hormozgan, stream and pools at Sar Khun (27º23'30"N, 56º26'E); CMNFI 1979-0206, 3, 24.4-25.1 mm standard length, Fars, qanat near Runiz-e Pa'in (29º12'N, 53º40'E); CMNFI 1979-0240, 3, 72.2-80.4 mm standard length, Fars, Lake Parishan (ca. 29º31'N, ca. 51º50'E); CMNFI 1979-0304, 5, 35.7-64.4 mm standard length, Fars, Lake Parishan (ca. 29º31'N, ca. 51º50'E); CMNFI 1979-0347, 2, 102.2-105.3 mm standard length, Fars, Pol-e Berengie (29º27'30"N, 52º32'E); CMNFI 1979-0352, 7, 79.4-101.5 mm standard length, Khuzestan, marsh in Jarrahi River drainage (30º33'30"N, 48º48'E); CMNFI 1979-0358, 1, 23.7 mm standard length, Khuzestan, pond southeast of Bostan (31º37'N, 48º07'E); CMNFI 1979-0360, 7, 14.1-64.2 mm standard length, Khuzestan, canal branch of Karkheh River (31º40'N, 48º35'E); CMNFI 1979-0364, 6, 21.2-54.9 mm standard length, Khuzestan, river at Abdolkhan (31º52'30"N, 48º20'30"E); CMNFI 1979-0371, 7, 17.8-36.6 mm standard length, Khuzestan, stream in Karkheh River drainage (32º05'N, 48º19'E); CMNFI 1979-0391, 1, 100.0 mm standard length, Khuzestan, stream in Marun River drainage (31º28'N, 49º51'E); CMNFI 1979-0687, 7, 124.8-154.1 mm standard length, Fars, Shiraz bazar (no other locality data); CMNFI 1979-0789, 4, 209.0-232.5 mm standard length, Fars, Lake Parishan (29º31'N, 51º48'E); CMNFI 1980-0151, 4, 177.6-212.3 mm standard length, Iran (no other locality data); CMNFI 1991-0154, 1, 232.8 mm standard length, Khuzestan, Hawr al Azim (ca. 31º45'N, ca. 47º55'E); CMNFI 1993-0126, 1, 172.9 mm standard length, Kermanshah, Sarab-e Yavari (34º28'N, 46º56'E); CMNFI 1993-0127, 1, 96.7 mm standard length, Kermanshah, Sarab-e Maran (34º44'N, 46º51'E); CMNFI 2007-0060, 2, 40.1-49.9 mm

standard length, Fars, Cheshmeh Ab-e Shirin near Lar (ca. 27º41'N, ca. 54º17'E); CMNFI 2007-0111, 1, 136.5 mm standard length, Kermanshah, Alvand River near Sar-e Pol-e Zahab (ca. 34º36'N, ca. 45º56'E); CMNFI 2008-0102, 2, 146.1-175.8 mm standard length, Kermanshah, sarabs near Kermanshah (no other locality data); CMNFI 2008-0120, not kept, Khuzestan, Rud Zard at Rud Zard (31º22'N, 49º43'E); CMNFI 2008-0130, not kept, Khuzestan, stream at Kupal (31º15'N, 49º10'E); CMNFI 2008-0135, 4, 83.1-128.5 mm standard length, Bushehr, lower Mond River (28º10'N, 51º16'E); CMNFI 2008-0151, 1, 141.5 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); CMNFI 2008-0163, not kept, Khuzestan, Marun River at Chahar Asiab (30º40'28"N, 50º09'34"E); CMNFI 2008-0168, not kept, Khuzestan, Dez River at Harmaleh (31º57'08"N, 48º33'48"E); CMNFI 2008-0241, 3, 108.4-125.0 mm standard length, Fars, Tangmohr River near Lamerd (27º02'02"N, 53º10'44"E); CMNFI 2008-0242, 5, 89.3-123.1 mm standard length, Fars, Ab Garm-e Aloo near Lamerd (27º20'02"N, 53º10'44"E); CMNFI 2008-0244, 5, 114.4-151.4 mm standard length, Fars, Qareh Bagh near Shiraz (29º30'N, 52º44'E); CMNFI 2008-0256, 5, 100.0-140.4 mm standard length, Fars, stream at Dimeh Mil-e Bala (30º06'52"N, 51º27'18"E); ZSM 21861, 5, 172.0-217.2 mm standard length, Khuzestan, Dez River at Harmaleh (31º57'N, 48º34'E).

Comparative material:- BM(NH) 1934.9.5:6, 1, 117.3 mm standard length, Kurdistan, Ain al Hamra, Shithatha (ca. 32º34'N, ca. 43º29'E); BM(NH) 1973.6.21:194, 1, 203.4 mm standard length, Iraq, Shatt al Arab (no other locality data); BM(NH) 1974.2.22:1338, 1, 134.9 mm standard length, Iraq, Najab Bazar (no other locality data); BM(NH) 1974.2.22:1346, 1, 108.7 mm standard length, Iraq, Tigris River near Faysh Khabur (ca. 37º08'N, ca. 42º38'E); BM(NH) 1986.2.14:4-7, 4, 98.6-146.6 mm standard length, Iraq, Baghdad (33º21'N, 44º25'E); CMNFI 1987-0017, 3, 97.3-143.9 mm standard length, Iraq, Hawr al Hammar (no other locality data).

### ***Carasobarbus sublimus***

(Coad and Najafpour, 1997)



*Carasobarbus sublimus*
Susan Laurie-Bourque @ Canadian Museum of Nature.

*Carasobarbus sublimus*, Fars, Fahlian River, after Borkenhagen and Krupp (2013).

*Carasobarbus sublimus*, 80.2 mm standard length,
ventral head, after Borkenhagen and Krupp (2013).

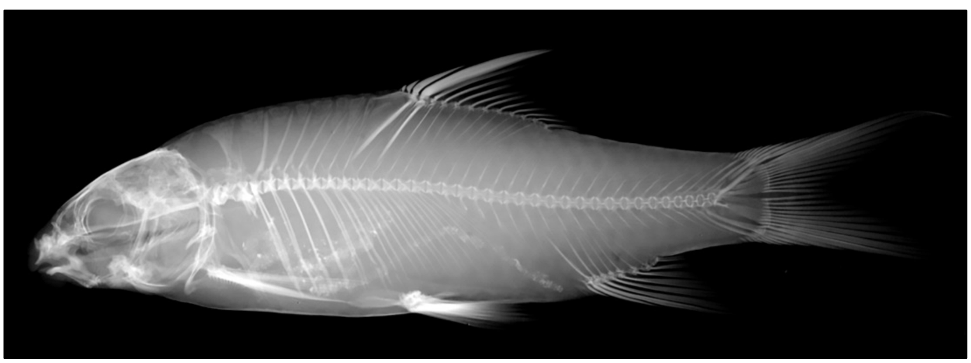
**Common names.** Sasmahi-ye Ala, hemri, zangol.

[Ala or sublime barb, Persian himri, Persian kiss-lip himri]

**Systematics.** The holotype of *Barbus sublimus* is CMNFI 1995-0009, female, 113.5 mm, Khuzestan, A`la River at Pol-e Tighen (31°23.5'N 49°53'E). Paratypes are CMNFI 1995-0009A, 41.9 mm, same locality as the holotype (lost in the mail while on loan September 2005), CMNFI 1995-0010, female, 115.3 mm, A`la River, 2 km above Pol-e Tighen (31°23.5'N 49°54'E), and CMNFI 1995-0011, 3 females, 90.5-98.6 mm, same locality as holotype (one specimen lost in the mail while on loan, September 2005).

*Barbus sublimus*, holotype, CMNFI 1995-0009, Brian W. Coad.

*Barbus sublimus*, holotype, CMNFI 1995-0009,
James Maclaine @ Canadian Museum of Nature.



*Barbus sublimus*, holotype, CMNFI 1995-0009,
Noel Alfonso @ Canadian Museum of Nature.

*Barbus sublimus*, paratype, CMNFI 1995-0011,
after Borkenhagen and Krupp (2013).

The species was named after its river of capture, then the only known locality for this species. A`la means "most high" or "exalted".

Borkenhagen *et al*. (2011) used limited molecular data (a small number of base pairs in the cytochrome *b* gene) and found evidence of paraphyly of *kosswigi* with *sublimus*, indicating a recent speciation event.

**Key characters.** This species is characterised by a unique combination of the following characters:- large scales (24-29 in the lateral line, 12 scales around the caudal peduncle), 37-38 total vertebrae, 9-11 dorsal fin branched rays (modally 10), 6 anal fin branched rays, a relatively short and smooth dorsal fin spine (spine length in head length 1.0-1.1), lower lip with a rounded median lobe and a posterior free flap, a compressed body (depth 3.3-3.5 in standard length), a short caudal peduncle (length in head length 1.5), long pelvic fins (length in standard length 4.1-4.5), and a short dorsal fin (longest dorsal fin ray in head length 1.1-1.2).

**Morphology.** The body is relatively deep and compressed, deepest at the dorsal fin origin. The predorsal profile is very convex. The caudal peduncle is compressed and relatively deep. The snout is rounded and overhangs the upper part of the thick upper lip, falling almost vertically to the lip. The extent of overlap varies individually. There is a groove in front of the nostrils. The lower lip is also thick but has a rounded protuberance at its centre, visible in lateral view. The protuberance is variably developed as a flap, which is free posteriorly and at the rearmost sides. The mouth is subterminal. The posterior barbel is longer and thicker than the anterior barbel. The anterior barbel extends back to under the nostril and the posterior barbel to the anterior eye. The rear of the eye is at the beginning of the anterior half of the head. The dorsal fin is slightly to strongly concave on its margin. The spine is strong but tapers and is thin and flexible at the tip. The dorsal fin origin lies over, or slightly anterior to, the pelvic fin origin. The caudal fin is deeply forked with the lower lobe more developed and with longer rays than upper lobe. The anal fin reaches or obviously passes the base of the caudal fin rays. This variation in length does not appear to be size or sex related. The posterior margin of the anal fin is straight to concave. The anus lies just anterior to the anal fin origin. The pelvic fin has a straight to rounded posterior margin and almost reaches to the anus. The pectoral fin margin is concave and in some fishes is falcate and the fin almost extends to the pelvic fin.

Dorsal fin branched rays 10(14), 11(1), anal fin branched rays 6(15), pectoral fin branched rays 14(3), 15(10) or 16(2) and pelvic fin branched rays 8(15). Borkenhagen and Krupp (2013) gave dorsal fin branched rays as 9(2) or 10(16). Lateral line scales 24(1), 25(7), 26(5) or 27(2) (Borkenhagen and Krupp (2013) gave 27(4), 28(3) or 29(4)), scales above the lateral line 4(1) or 5(5), scales below the lateral line 4(3) or 5(3), scales between lateral line

and pelvic fin 3(6), predorsal scale rows 9(5) or 10(1), and caudal peduncle scales 12(5). Scales are regularly arranged over the whole body, there is a pelvic axillary scale, and scales at the anterior base of the anal fin form a small sheath around the bases of the anal rays. Scale shape is squarish, the posterior margin is rounded and is shallow or protruding, the dorsal and ventral margins are straight to slightly rounded, the anterior corners are abrupt and rounded, the ventral corner is more rounded than the dorsal corner, and the anterior margin has a small to wide and shallow central protrusion with an indentation above and below and this margin is quite vertical. Radii are found on the anterior and posterior fields of each scale, being most numerous posteriorly, about three times as many. Some radii extend into the lateral fields. Circuli are numerous and on the posterior field break up into tubercular shapes. Total gill rakers number 10(3), 11(2), 12(7) …. or 15(1), but note counts may be size-related Total vertebrae number 37(4) or 38(7). The holotype has 37 total vertebrae. Jawad *et al*. (2017) gave details on the vertebrae. Esmaeili *et al*. (2006) gave the following characters for their six specimens from Fars:- dorsal fin branched rays 11, anal fin branched rays 6-8, pectoral fin branched rays 16-18, lateral line scales 24-28, and total gill rakers 10-12. Gill rakers are short and reach to the adjacent raker when appressed. Pharyngeal teeth are rounded with a hooked tip and a flattened area below the tip. On three specimens counts were 2,3,5-4,3,2, 1,3,5-4,3,2 and 3,3,4-4,3,2. The gut is elongate with anterior and posterior loops.

**Sexual dimorphism.** Unknown.

**Colour.** The overall live colour of the species is silvery with the back olive-green. Scales are outlined with dark pigment. The pectoral, pelvic, anal and caudal fins are faintly pigmented with orange to yellow hues, most apparent when the fin is collapsed. These fins are mostly grey to hyaline. The dorsal fin is grey to hyaline and may be dark at the tip. The iris is silvery with grey-brown pigment at the upper margin. The peritoneum is silvery with numerous melanophores merging to give an overall dark appearance.

In preservative, the pigmentation pattern is as follows. Upper to mid-flank scales have the margins and bases pigmented with melanophores, outlining the scales. Most pigment is concentrated at the scale base giving a slight appearance of rows of spots. Larger fish are more fully pigmented so the back and upper flank then appear dark. The dorsal surface of the head is finely speckled black. The dorsal fin has dark pigment on the membranes, on the distal half or the whole fin, with less pigment on the rays. The caudal fin is mostly hyaline with dark pigment lining the rays. The pectoral and anal fins have some dark pigment lining or on the anterior rays and, in larger fish, on the membranes. The pelvic fin is hyaline. The smallest specimen has a distinct mid-caudal base spot and another spot on the back at the anterior dorsal fin base. Fins are more hyaline than in larger fish.

**Size.** The maximum size is 15.5 cm (*Iranian Fisheries Research and Training Organization Newsletter, Tehran*, 18:5, 1997).

**Distribution.** This species is found in the Persis and Tigris River basins and is endemic to Iran. In the Persis basin recorded from Fahlian, Kheyrabad and Tang-e Shiv rivers and headwaters of the Zohreh; and in the Tigris River basin known from the A'la, Jarrahi and Marun rivers (and possibly the Kashkan River in a more northern part of the Tigris River basin (Borkenhagen and Krupp, 2013), the specimen from CMNFI 1979-0277 corresponding to *C. sublimus* in scale count (29) but *C. kosswigi* in total vertebrae (39) indicating more work needs to be done to distinguish these species (Esmaeili *et al*., 2006, 2015; Zamaniannejad *et al*., 2015; Fatemi *et al*., 2019). Jouladeh-Roudbar *et al*. (2020) also recorded it from the Simareh River and the Dez and Karun dams.

The record in the upper reaches of the Shatt al Arab, Iraq by Mohamed *et al*. (2017) is not this species from the description and resembles *C. luteus*. K. Borkenhagen also noted this in comments on ResearchGate (downloaded 27 February 2017). Similarly, a record and description of biology of fish from the Al-Diwaniya River in the Euphrates River basin of Iraq by Mohamed and Al-Jubouri (2018, 2019) are also *C. luteus* and this too is noted in comments on ResearchGate by K. Borkenhagen for this record (downloaded 27 January 2018).

**Zoogeography.** This species is known from the A`la River, which joins with the Rud Zard or Zard Rud (rud = river), and emerges from the foothills of the Zagros Mountains onto the Khuzestan plains where it is tributary to the Jarrahi River. The Jarrahi feeds the Shadegan Marshes and is mostly lost there. In flood times, there may be a connection through the marshes to the Karun River and thence to other large river systems in the Tigris-Euphrates basin. However, it is suspected that the ecological requirements of this species limit it to fast flowing rivers over hard substrates and the marsh system isolates it from other river systems. Collections in the Rud Zard at Rud Zard village and Bagh-e Malek on several occasions did not include this species although a later collection was made in the Rud Zard.

The range extension of 380 km southwest of the A`la River to the Fahlian River near Noorabad in Fars places this species in the headwaters of the Zohreh River which drains to the northern Persian Gulf (Persis basin). This may indicate headwater captures or possibly former interdigitating drainages on the Khuzestan plain.

**Habitat.** This species is found in rivers and streams. The type habitat was a cloudy river in a wide flood plain at about 800 m. The river bed was stones and pebbles and at low water the shore was barren or grassy. Water was led off from the river at intervals to irrigate the rice fields of the villages of Meydavud-e `Olya (31°24'N. 49°52'E) and Meydavud Pa'in (31°23'N. 49°49'E) which extend along the bank of the A`la River. This water abstraction is a potential threat to the well-being of fishes in this river system. The water demands of rice growing are large and there is little or no rain through the summer months in this area. Air temperatures in September can exceed 40°C and evaporation from the fields and the river is commensurate.

The fish were caught at the type locality in relatively fast water (0.9 $m.s^{-1}$) over a one-hour fishing period. In September 1995, the river was at the seasonal low water and the type locality was 10 m wide, 40 cm deep and had a discharge of ca. 2.9 cu m/s. The water was also cloudy for the collection in December 1994 at the type locality but the river was wider and had more flow after rain. The second locality had more flow and was deeper and wider than the type locality, to about 30 m and 80 cm. Fishes were caught by electroshocker and cast-net and were difficult to catch and few in number. Other species captured were the cyprinoids *Arabibarbus grypus*, *Barilius mesopotamicus*, *Capoeta trutta*, *Cyprinion macrostomus*, *Garra rufa* and *Luciobarbus barbulus*, and the sisorid catfish *Glyptothorax silviae*.

Type locality of *Carasobarbus sublimus*, CMNFI 1995-0009,
Khuzestan, A`la River at Pol-e Tighen, 20 September 1995, Brian W. Coad.

The Fahlian River capture site was shallow, had relatively clear water, a heterogenous bed morphology (sand, gravel, stone, pebble, rock, etc.), and an absence of aquatic and riparian vegetation (Esmaeili *et al*., 2006).

Habitat of *Carasobarbus sublimus*, Fars, Fahlian River at Pol-e Fahlian,
Hamid Reza Esmaeili.

**Age and growth.** Unknown.
**Food.** Unknown.
**Reproduction.** Unknown.
**Parasites and predators.** None reported.

**Economic importance.** None reported.

**Experimental studies.** None.

**Conservation.** Known only from a few localities, its conservation status is unknown. It appears to be rare and possibly restricted to areas with running water year-round. Jouladeh-Roudbar *et al*. (2020) listed it as Vulnerable.

**Sources.** Type material:- *Barbus sublimus* (CMNFI 1995-0009, CMNFI 1995-0009A, CMNFI 1995-0010 and CMNFI 1995-0011).

Iranian material:- CMNFI 1979-0277, 1, 116.5 mm standard length, Lorestan, Kashkan River drainage (33º30'N, 47º59'30"E); CMNFI 2008-0161, 1, 79.7 mm standard length, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 2008-0170, 3, 78.8-85.5 mm standard length, Khuzestan, Zard Rud (31º22'28"N, 49º43'15"E); CMNFI 2008-0171, 4, 42.9-76.3 mm standard length, Khuzestan, A`la River at Pol-e Tighen (31º23'20"N, 49º52'44"E); CMNFI 2008-0260, 1, 71.5 mm standard length, Fars, Zohreh River (no other locality data).

## Genus *Carassius*
Jarocki, 1822

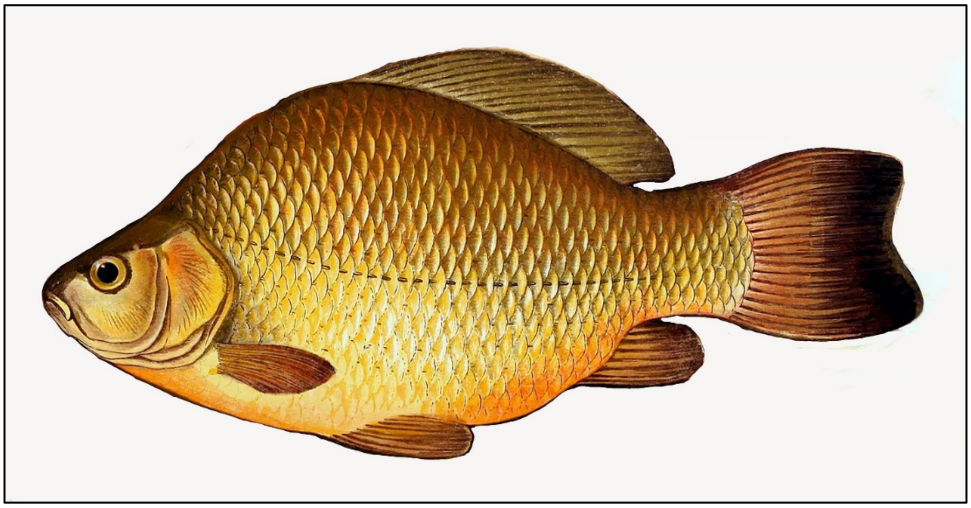
The goldfishes comprise about seven species found in Europe, northern Asia and the Far East (Kottelat, 2017). Eschmeyer (1990), Kottelat (1997, 2017) and the *Catalog of Fishes* commented on the authorship of *Carassius*. One or two species are now common exotics in Iran.

These fishes are characterised by a stout and compressed body, last dorsal fin unbranched ***and*** anal fin unbranched rays a finely serrated spine, long dorsal and short anal fin, mouth small and terminal, lips thick and fleshy, no barbels, pharyngeal teeth in one row and molariform but compressed, numerous gill rakers, and scales large.

Moghaddas *et al*. (2021) found *Carassius* species were very high-risk threats to the Anzali Wetland complex, with *C. auratus* and *C. gibelio* achieving the highest scores in this respect among 29 non-native species tested (although only 13 species were currently known from the wetland). These goldfishes have a high tolerance to environmental changes and stresses and reproduce gynogenetically, which accounts for their global invasiveness (and see below also).

The crucian carp, *Carassius carassius* (Linnaeus, 1758) has been reported as introduced to Iran in the Karun River basin as aquarium releases by Armantrout (1980) without further details and there are other reports such as in the Gorgan River (Y. Keivany, *in litt*., 1992) and Mahabad Dam (Abdi, 1999; www.mondialvet99.com, downloaded 31 May 2000), and in various papers (see below under **Distribution**) but some of these may be confusion with *Carassius auratus*. Specimens with DNA material would be needed to confirm the identity in Iranian studies. The native distribution is in Europe and Western Asia, reaching northern drainages of the Caspian Sea in the southern limits of its natural distribution (Libosvárský, 1962). It differs from *C. auratus* in having a slightly convex margin to the dorsal fin (straight or slightly concave in *C. auratus*), caudal fin slightly emarginate (deeply emarginate), usually 6 branched anal rays (usually 5), 23-33 total gill rakers (34-54), 31-34 vertebrae, usually 32-33 (25-34, usually 29-30), 28-29 fin denticles posteriorly on the dorsal fin spine (10-11), peritoneum light (dark), black spot at the caudal fin base in young and some adults (absent), and a coppery gold body (silvery, pinkish gold, gold or red) (Szczerbowski in Bănărescu and Paepke, 2002; general literature). Berg (1948-1949) also cited the characters body rounded,

back thick (body angular, back compressed) and scales weakly sculptured (rough), although his comparison was with *C. a. gibelio*, itself recognised as distinct (*Carassius gibelio* (Bloch, 1782), the Prussian carp), also of uncertain occurrence in Iran.



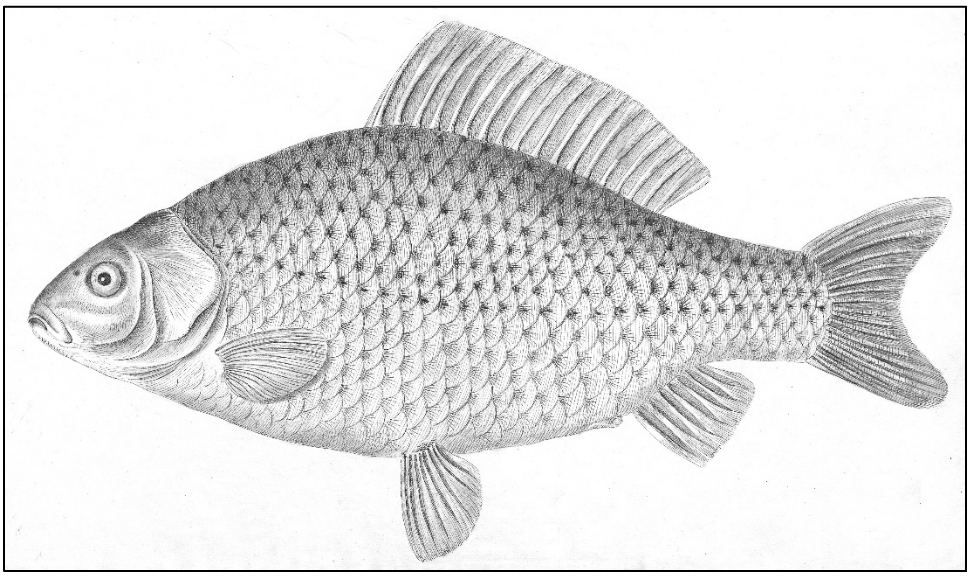
*Carassius carassius*, after *British Fresh-Water Fishes* by Rev. William Houghton (1879).

*Carassius carassius*, aquarium specimen, Prague (CC0, Karelj).

Masson *et al*. (2011) used head and pectoral girdle bones to distinguish *Carassius* species. *C. auratus* has an opercular fovea with an undulated anterior margin and acute lower margin, a very plain internal surface, and the opercular crest is highly developed with numerous strong accessorial crests. *C. gibelio* also has a plain internal surface to the operculum but the upper margin has small concavities around the auricular process. The external margin of the cleithrum has a concavity in the middle part of the dorsal limb in *C. auratus* (rounded in *C. gibelio* and *C. carassius*). The *C. carassius* cleithrum is very similar to that of *C. gibelio* but

has a more rounded tip of the external crest in the ventral limb and a small incisure in the internal margin next to the dorsal spine. In the ventral limb of the pharyngeal arch, the dorsal extreme of the ventral apophysis is more pointed in C. *carassius* than the other two species and the anteriormost tooth is the thinnest (thickest in the other two species). The external angle of the pharyngeal arch is pointed in *C. auratus* and rounded in the other two species with *C. gibelio* being the only species with a tip below the external angle.

Yerli *et al*. (2014) separated the three *Carassius* species found in Turkey (and presumably Iran) as follows. *C. auratus* and *C. gibelio* have a concave-straight free edge to the dorsal fin (convex in C. *carassius*) and a strongly serrated last dorsal and anal fin unbranched rays (weakly serrated in *C. carassius*). Their gill raker counts are *auratus* = 38-47, *gibelio* = 37-52, *carassius* = 23-33, and lateral line scales are *auratus* = 26-31, *gibelio* = 29-33 and *carassius* = 31-36. Ali (2008), examining fish from southern Iraq, concluded these were C. *gibelio*. Habbeb (2014) examining 110 fish from Basra, Iraq identified as *C. auratus auratus* cited 42-44 gill rakers (a narrow range for so many fish), 25-27 lateral line scales and 25-27 vertebrae (presumably not including four Weberian vertebrae and possibly the caudal complex). Note that Kottelat (2017) gave a count of 35-54 for gill rakers in *C. gibelio* and he indicated that this species presents a number of taxonomic problems.



*Carassius gibelio*, after Bloch (1782).

*Carassius gibelio*, Hungary, River Tisza
(CC BY 3.0, Akos Harka).

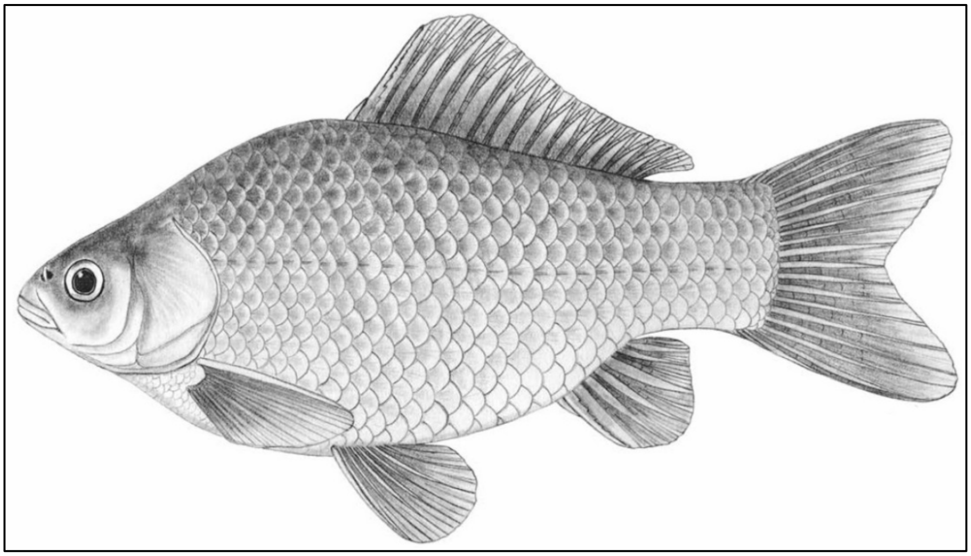
Kalous *et al*. (2013) noted that *C. auratus* and *C. gibelio* are morphologically very similar and reliable identification is not possible on morphological characters (and the same applies to *C. langsdorfii* recently reported from Iran based on cytochrome *b* data (Khosravi *et al*., 2020)). *C. carassius* and *C. gibelio* have long been known as native in Europe while *C. auratus* was domesticated in China and introduced to Europe in the 17$^{th}$ century and now has many feral populations. Kalous *et al*. (2013) also found a wide distribution of another *Carassius* species, the Japanese ginbuna *C. langsdorfii* Temminck and Schlegel, 1846, in Europe, presumably an accidental introduction with koi carp (*Cyprinus carpio*) or *C. auratus* juveniles. The Japanese ginbuna was also a potential exotic in Iran (now confirmed, see above). Rylková *et al*. (2013) used cytochrome *b* to examine European populations of *Carassius*, complementing the previous study. They found at least one undescribed species in Europe, noted that diploid and triploid specimens occur in *auratus* and *gibelio*, and hybrids between *Carassius* species occur and are difficult to identify. Hybrids also occur between *Carassius* and *Cyprinus carpio* to further confuse identifications (Halas *et al*., 2018) but they sequenced cytochrome *b* in *Carassius* specimens from across North America and were able to identify *C. auratus* (the majority of specimens) and *C. gibelio* as well as *C. langsdorfii*.

The composition of *Carassius* species in Iran was under study by Milad Khosravi (pers. comm., November 2014) and Khosravi *et al*. (2020) identified *Carassius auratus, C. gibelio* and *C. langsdorfii* in inland waters of Iran based on cytochrome *b*. *C. carassius* was not recorded and the study examined material from the Anzali Wetland in Gilan (*C. gibelio*), the Hamun-e Saberi in Sistan (*C. auratus*), the Karun River and Shadegan Wetland in Khuzestan (*C. auratus*) and the Siah Palas Stream in Tehran (*C. langsdorfii*). The Anzali Wetland material was based on four samples but from a single locality and so does not preclude the presence of *C. auratus* also in that wetland. Iranian literature records and studies are included under the *C. auratus* account below, even if another species was identified in the text, as such identifications remain uncertain in the field, in the laboratory and in literature based solely on morphology. Ideally, any study should preserve material for DNA analysis and confirmation of identity. Goldfish species cited generally in the text are left as in the original with the understanding that they could be any one of the three species identified above by DNA analysis but many are most likely to be *C. auratus*.

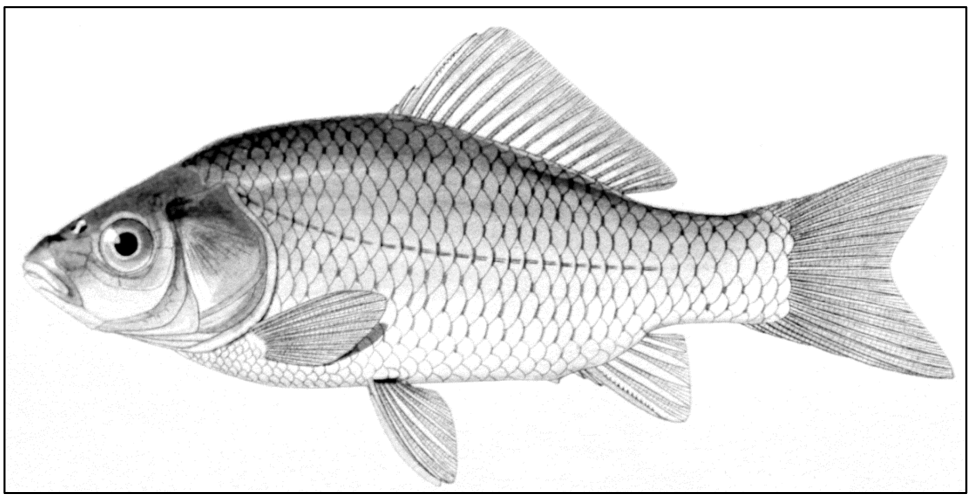
*Carassius langsdorfii*, Naturalis Biodiversity Center (CC0).

*Carassius langsdorfii* , Kamo Aquarium, Japan
(rotated, CC BY-SA 4.0, Totti)

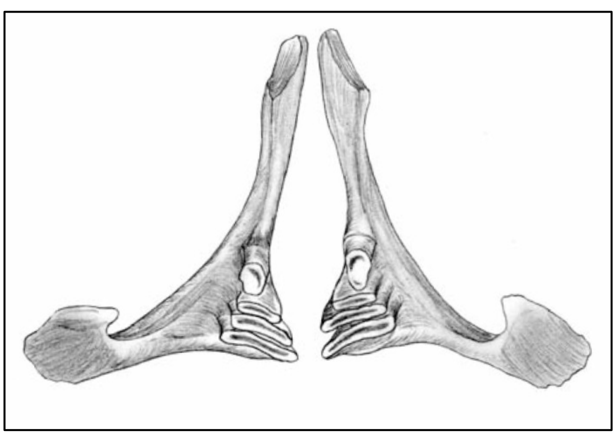
***Carassius auratus***
(Linnaeus, 1758)



*Carassius auratus*, 123.0 mm standard length
(CC0, U.S. Geological Survey).

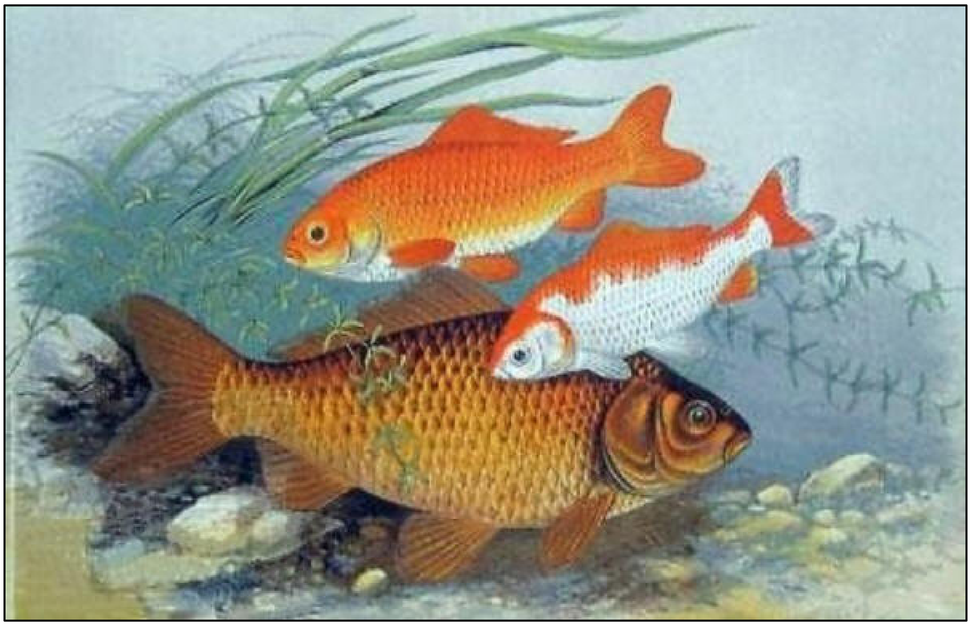


*Carassius auratus* (= *C. a. gibelio* morpha *humilis*), 13.0 cm total length, ZISP 16835, Russia, Lake Khasan in the Tumen'ula River basin, after Berg (1948-1949).



*Carassius auratus*, 123.0 mm standard length,

pharyngeal teeth (4-4)
(CC0, U.S. Geological Survey).



*Carassius auratus*, after *British Fresh-Water Fishes* by Rev. William Houghton (1879).

**Common names.** Mahi-ye talaee, mahi-ye talai or mahi talayi (= gold fish) or ooshin or oushein in Khuzestan; kapur sefid by anglers in Khuzestan at Ahvaz (= white carp); kopur-cheh (= small carp) or karas, karass or karaz in Mazandaran (from the scientific name); kopur cheky, kopur chekeh or kaporche (= cheque carp, Y. Keivany, pers. comm., 25 September 2018); mahi-ye howz or mahi-e-hoz (= pond or pool fish), mahi-ye howz-e noqrehi (= silvery pond fish, for silvery form), mahi-ye howz-e talaee (= golden pond fish, for orange form), carassin, red fish.

[Samak zahabi (= golden fish), yaybash in Basrah (from the Turkish yay meaning bow, arch or curved, and bash meaning head); karseen in Baghdad (possible a Syrian place name or from karsin, meaning paunchy, gluttonous (all previous from Mikaili and Shayegh (2011)); buj-buj in Nasiriyah, carp thahabi and samti, all in Iraqi Arabic; Kirmizi havuz balığı for *auratus* and Havuz balığı and Çin sazanı for *gibelio* in Turkish (Çiçek *et al*., 2020; Kaya *et al*., 2020); serebryanyi karas or silver crucian carp for *gibelio* in Russian; goldfish for *auratus*, Prussian carp and European goldfish for *gibelio*].

**Systematics.** *Cyprinus auratus* was originally described from China and Japanese rivers. Pelz (1987) discussed the scientific name of the goldfish and its confusion with *Carassius carassius*. All diploid goldfish of Western Europe are *Carassius auratus auratus* (from introductions, presumably including releases and escapes in Iran) and all triploid goldfish are *C. auratus gibelio* from eastern areas. Bai *et al*. (2011) also considered triploid and polyploid individuals to be *C. auratus gibelio.* Goldfish do not appear to be native to Iran. Iranian specimens are sometimes referred to *Carassius auratus gibelio* (Bloch, 1782) known as the Prussian carp, European goldfish or silver crucian carp. Berg (1948-1949) considered the familiar pet “goldfish” to be a domesticated form of the Prussian carp. However, these fish probably have a number of origins - from aquarium stock and from China. Kottelat (1997) tentatively recognised *Carassius gibelio* (Bloch, 1782) as a species native to eastern Central

Europe, and Kottelat and Freyhof (2007) map *gibelio* as the introduced species in the Caspian Sea basin of Iran. Vasil'eva and Vasil'ev (2000) stated that fish named in the literature as *Carassius auratus gibelio* from Europe, Siberia and eastern Asia are triploids and are not a valid subspecies of *C. auratus s.s*. They considered *C. gibelio* to be a distinct species as long as it has a unique and ancient origin rather than arising *de novo*, and as long as the type specimens are triploids. Szczerbowski in Bănărescu and Paepke (2002) recognised *C. a. auratus* and *C. a. gibelio*. Kalous *et al*. (2012) referred to *C. carassius* from most of Europe and western Siberia, *C. gibelio* in Europe, Siberia and northeast Asia, with *C. auratus* in mainland East Asia (and presumably widely introduced). Diploid and triploid individuals of *C. gibelio* occur in many populations, complicating species definition. Using cytochrome *b*, Kalous *et al*. (2012) demonstrated that *C. gibelio* may comprise two species under that name. Taati *et al*. (2010, 2010a, 2010b) considered their experimental material from a hatchery at Nahar Khoran, Gorgan to be Prussian carp. Khaefi *et al*. (2013) examined fish from the Helleh River and Arjan Wetland in the Persis basin, Saqqez in the Lake Urmia basin, the Sefid River and the Kor River. The latter was completely separate morphometrically from the other populations leading to the possible conclusion that both *C. gibelio* and *C. auratus* are present in Iran. Doğaç *et al*. (2015) examined goldfish, *C. auratus*, in western Anatolia using four mitochondrial genes and found populations to have originated from the common haplotype in native East Asian populations. Additionally *C. auratus* may be a tetraploid derivative of *Carassius carassius.* Karabanov *et al*. (2020) in their review of exotic species in the Volga River basin referred to a *Carassius auratus* complex, indicating the difficulty of separating *Carassius* species there.

Ahmadi *et al*. (2016) found significant differences in body shape between fish from the Sefid River and Lake Alagol attributed to environmental factors. Niazie *et al*. (2013) examined 30 specimens morphometrically before, and after, preservation in 10% formalin finding total, standard and head length all showed shrinkage. Eagderi *et al*. (2020) examined 119 fish identified as *C. gibelio* from Alagol Lake, the Khoda-Afarin Dam and the Mashkil and Sefid rivers for morphometric characters and found fish from Alagol and Khoda-Afarin had a deeper body and a smaller head, those from the Sefid had a deeper body but also a larger head similar to the Mashkil fish. The lotic fish grouped together separate from the lentic fish and body shape was based on habitat.

Al-Mukhtar and Al-Hassan (1999) described a hybrid of this species and *Barbus* (= *Mesopotamichthys*) *sharpeyi* from Al-Hayei (= Al Ha'i), a seasonal lake between the Karkheh and Dez rivers in Khuzestan. Jawad *et al*. (2012) reported *C. gibelio* from Basrah Province of southern Iraq, distinguishing it from *C. auratus* and *C. carassius*.

Goldfish commonly hybridise with *Cyprinus carpio* to further confuse the identity of these fishes (L. Nico, http://nas.er.usgs.gov/fishes/accounts/cyprinid/ca_aurat.html, downloaded 24 May 2000).

The *Carassius* species in Iran is generally regarded as *C. auratus*, the goldfish of aquaria, as it is cultivated in Iran and used extensively in Now Ruz (New Year) celebrations and often released into natural waters. This needs confirmation for all major populations.

**Key characters.** The combination of spines in both the dorsal and anal fins and the absence of barbels is unique to this species in Iran. Szczerbowski in Bănărescu and Paepke (2002) distinguished the subspecies *auratus* from *gibelio* by 21-36 lateral line scales (27-35 in *gibelio*) and a pink or gold colour (yellowish-silver), not very diagnostic. Ilhan *et al*. (2005) gave gill raker numbers of 34-40 for *auratus*, 42-56 for *gibelio* and 25-32 for *C. carassius* in Turkish waters (however, note that counts can increase with growth, and see below). See also

above for other putative distinguishing characters.

**Morphology.** Morphology can be very variable as would be expected from fish bred for aquaria, with over 300 breeds, from multiple origins, and released into various constraining habitats. There are elongate specimens (morpha *humilis*, where fish density is high) and deep-bodied specimens (morpha *vovki*, where fish density is low). The following varying comments are based on fish from Iran but do not necessarily cover all body shapes likely to be found there. The body is compressed or thick, rounded and stocky, and moderately deep to very deep. It may be deepest just behind the head or just in front of the dorsal fin origin. The dorsal profile in front of the dorsal fin is gently to very convex, falling sharply to the snout after the occiput, or convex to the occiput where, after an inflexion point, the profile is straight to the snout tip. The dorsal body margin under the dorsal fin and anteriorly on the back is compressed. The caudal peduncle is compressed and deep. The eye can be large to relatively small, in the anterior half of the head or overlapping the half way point of head length. The snout is rounded. The mouth is oblique and terminal to subterminal. The upper lip is thin and the lower lip broad. The dorsal and anal fin spines are moderately developed with moderate sized denticles reaching almost to the tip. The dorsal fin margin is concave to straight with the fin height decreasing posteriorly. The dorsal fin origin lies in advance, over, or behind the level of the pelvic fin origin. The dorsal fin insertion lies over the middle of the anal fin. The caudal fin is moderately forked with a pointed upper tip and a rounded lower tip, or both tips may be rounded. The anal fin margin is straight to rounded and the fin extends back to, or falls short of, the caudal fin base. The pelvic fin margin is rounded and the fin extends back to the anus or falls well short of it. The pectoral fin margin is rounded and the fin extends back to the pelvic fin.

Dorsal fin with 3-4 unbranched rays followed by 12-20 branched rays, anal fin with 2-4, usually 3, unbranched rays followed by 5-6, usually 5, branched rays, pectoral fin branched rays 11-18, and pelvic fin branched rays 6-9, usually 8. Dorsal and anal fin spine denticles are coarse and few (about 10-15). Lateral line scales 21-36. Scale shape is rounded to squarish with a shallowly rounded posterior margin, rounded to almost straight dorsal and ventral margins and a wavy anterior margin with 1-4 protrusions. Anterior scale corners are rounded and can protrude. There are very few anterior and posterior radii, as few as 3-4. The focus is slightly subcentral posterior. Circuli on the exposed part of the scale are coarser and widely spaced than on the concealed part of the scale. Gill rakers are long with serrated interior margins, reaching the fifth to eighth raker below when appressed with younger fish having longer rakers proportionately. Counts are size dependent in the range 34-54. All meristic counts may be conflated with other species as authors conflict on counts. The above are maximum ranges and limited samples will have much smaller ranges. Pharyngeal teeth are 4-4, with very elongate, narrow, flattened and horizontal cusps arising from a much narrower stem. The gut is coiled with several loops. Total vertebrae number 25-34. This species is variously reported as only diploid or as a tetraploid (2n = 100-162); see above, with *gibelio* 2n = 98-162 (Arai, 2011).

Rahmati-holasoo *et al*. (2014) described fish from Pirhayati village in Hamadan with lordosis, scoliosis, kyphosis, short mandibles, posterior swimbladder depletion and complete lack of fin rays. These abnormalities could be due to inbreeding, nutritional deficiencies or pollutants. Abdullah (2016) described the osteology of the premaxilla, maxilla, lower jaw and operculum of fish from Iraq identified as *C. gibelio*. Zakeri Nasab *et al*. (2018) described the morphology and histology of the gut and accessory glands in this fish.

Meristic values for Iranian specimens are:- dorsal fin branched rays 16(4), 17(3), 18(3), 19(5) or 20(2), anal fin branched rays 5(17), pectoral fin branched rays 11(1) …., 14(1), 15(4), 16(10) or 17(1), pelvic fin branched rays 7(2) or 8(15), lateral line scales 28(6), 29(9) or 30(2), pharyngeal teeth 4-4(10), and total vertebrae 32(2).

**Sexual dimorphism.** Breeding males have small nuptial tubercles on the operculum, back and pectoral fin rays.

**Colour.** The golden or orange colour of artificially bred aquarium goldfish is distinctive. However, populations in the wild, if they breed successfully, gradually revert to a wild-type of colour, without the appropriate diet supplement given to aquarium fish and, as golden fish, are readily seen and eaten by birds and other fishes. Yanar and Tekelioğlu (1999) found that pigmentation increased with fish weight when specimens were fed the carotenoid zeaxanthin. Wild-type colour is an overall olive-green fading to a white belly. Flanks can be silvery to almost black. Fins are a dark olive-bronze, the membranes in particular being heavily pigmented. Young goldfish are usually green, brown or bronze to almost black and only after about one year do they take on the colour of adult *auratus* or *gibelio*. The peritoneum is dusky to black.

Young fish in the Karun River at Ahvaz, Khuzestan, however, are a bright silvery overall (more so than *Cyprinus carpio* of similar size), the back is grey, the caudal fin is grey on the proximal half and hyaline distally, and the anal fin rays are white (and thus partly resemble *gibelio*).

The Prussian carp (*C. gibelio*) is a dark steel colour with dark blue or greenish dorsally, silver-grey laterally and white ventrally, dorsal and caudal fins are dark grey and the paired fins and anal fin are light pinkish (Szczerbowski in Bănărescu and Paepke (2002).

**Size.** Attains 62.0 cm and about 5.0 kg, the taxon *gibelio* being smaller, up to 45.0 cm and 1.24 kg.

**Distribution.** The native distribution is in northern Asia and China, reaching northern drainages of the Caspian Sea in the western limits of its distribution (Libosvárský, 1962; Pelz, 1987). The goldfish has been widely introduced to garden ponds and released from aquaria in temperate to warm waters world-wide. In Iran, it is found in many garden and park ponds. Some introductions are discarded aquarium fish as goldfish are sold as pets and for the Now Ruz (= New Year) festivities. It may also have been introduced accidentally with the commercially important Chinese carps. Fish are usually identified as *C. auratus* and occasionally as *C. auratus gibelio*, *C. gibelio* or *C. carassius*, some of which are indicated below. Sykes (1898) was an early mention of "goldfish", possibly this species, in garden ponds at Kerman, Rasht and Yazd (but perhaps native fish such as *Capoeta* spp.).

In Iran this species has been reported from the Caspian Sea, Dasht-e Kavir, Dasht-e Lut, Esfahan, Hamun-e Jaz Murian, Hamun-e Mashkid, Hari River, Hormuz, Kerman-Na'in, Kor River, Lake Maharlu, Lake Urmia, Namak Lake, Persis, Sistan and Tigris River basins, and undoubtedly is found in all basins. See also the localities in biology accounts below. In the Caspian Sea basin in the Ahar, Aras (including the middle Aras and lower reaches of its tributary the Qareh Su), Atrak, Babol, Chalus, Ghotor, Gorgan, Haraz, Haviq, Kargan, Kazem (as *gibelio*), Kelarud, Nesa (as *gibelio*), Pir Bazar (as *C. auratus* and *C. gibelio*), Polrud (= Pol-e Rud), Qezel Owzan, Rasteh, Rudbar, Sardab, Sefid, Selin Chay, Shalman (as *gibelio*), Sheikan, Shirud, Shurab, Siah, Siah Darvishan, Tajan, Talar, Tonekabon, Tutkabon and Zangbar rivers, the Anzali Talab and rivers where it is now the most abundant fish (recorded variously as both *auratus* and *gibelio*), Gorgan Bay, Ulmogol and Alagol lakes, Amirkelayeh

and Boojagh wetlands, Fereydun Kenar International Wetland, Nur or Neor Lake (as *C. gibelio*), the Alakoli, Arasbaran, Boostan, Golabar, Golestan, Sattarkhan and Taham dams (as *C. gibelio*) and Voshmgir dams (as *auratus* or *gibelio*) and the Karfestan Ab-bandan at Rudsar (Holčík and Oláh, 1992; Roshan Tabari, 1997; Shamsi *et al*., 1997; Karimpour, 1998; Abbasi *et al*., 1999; Kiabi *et al*., 1999; Nasrollahzadeh, 1999; Abdoli, 2000; Gasmi and Mirzaei, 2004; Khara *et al*., 2006a; Abbasi *et al*., 2007; Masoumian, 2007; Banagar *et al*., 2008; Patimar, 2008; Abdoli and Naderi, 2009; Hajirostamloo, 2009; Piri *et al*., 2009; Ashoori, 2010; Mirzajani, 2010; Khara *et al*., 2011; Ahmadpour *et al*., 2012; Mirzajani *et al*., 2012; Rasouli *et al*., 2012; Ahmadi *et al*., 2013, 2016; Abdoli *et al*., 2014; Gholizadeh *et al*., 2014; Hajirad Kochak *et al*., 2016, 2016a, 2016b; Hajiradkochak *et al*., 2016; Khodaparast Sharifi *et al*., 2016; Salavatian *et al*., 2016; Abbasi *et al*., 2017; Babaei, 2017; Naderi Jolodar *et al*., 2017; Zamani Faradonbe *et al*., 2017; Shahnazari *et al*., 2020); in the Dasht-e Kavir basin generally (Jouladeh Roudbar *et al*., 2015; Pourgholami Moghaddam *et al*., 2018); in the Dasht-e Lut basin generally (Abdoli, 2000); in the Esfahan basin in the Zayandeh River and Dam (Shamsi *et al*., 2009; Tavakol *et al*., 2015; Jouladeh-Roudbar *et al*., 2020); in the Hamun-e Jaz Murian basin in the middle Halil and middle to lower Bampur rivers (Abdoli, 2000; Ebrahimi, 2001; Ebrahimi *et al*., 2002); in the Hamun-e Mashkid basin in the Rotak River (Esmaeili *et al*., 2013a, 2013b; Malekzehi *et al*., 2014; Esmaeili *et al*., 2015); in the Hari River basin in the Kardeh Dam as both *C. auratus* and *C. gibelio* (Esmaeili *et al*., 2013; Abbasi *et al*., 2016; Asgharnia *et al*., 2018; Mousavi-Sabet *et al*., 2018); in the Hormuz basin in the Kul River; in the Kerman-Na'in basin generally (Abdoli, 2000) and in a pool at the Desert Anthropology Museum in the Pirnia House in Na'in (image file "Water pond in the lower courtyard" from Wikimedia Commons; in the Kor River basin in Kaftar and Kamfirouz lakes, and the Dorudzan Dam (as *C. gibelio*) (Teimori *et al*., 2010; Sayyadzadeh *et al*., 2016; Zamanpoore and Yaripour, 2017; Paighambari *et al*., 2020); in the Lake Maharlu basin in the Khoshk River (presumably when it is not dry) and in garden ponds (personal observations) and even the qanat stream under Sa`di's Tomb (Coad, 2015b, 2015d); in the Lake Urmia basin in the Baranduz, Ghale (= Qal'eh), Hasanlu, Mardogh, Nazlu, Qader, Saqqez, Simineh, lower Talkheh (= Aji) and Zarrineh rivers (some as both *C. auratus* and *gibelio*), the Mahabad River and Dam, Ghalehchai (= Qal'eh) Lake (both *C. auratus* and *gibelio*), Ghaleh Khani and Shaharchay dams (Abdoli, 2000; Mirhasheminasab and Pazooki, 2003; Abbasi *et al*., 2005; Mohaghegh, 2008; Esmaeili and Gholamifard, 2011; Rasouli *et al*., 2012, 2017; Rasuli *et al*., 2012; Moradi and Eagderi, 2014; Ghasemi *et al*., 2015; Dadai Ghandi *et al*., 2017; Eagderi and Moradi, 2017; Zamani Faradonbe *et al*., 2017; Fathi and Ahmadifard, 2019); in the Namak Lake basin in the upper and lower Qareh Chay, the lower Shur and the Siah rivers, and the Kabir and Latian dams (Armantrout, 1980; Hosseini, 1987; Abdoli, 2000; Abbasi, 2009); in the Persis basin in the Dalaki, middle and lower Helleh, lower Mond and Shapur rivers, the Howba Spring (a hot sulphur spring) and Lake Parishan (latter sometimes listed as *C. carassius*, presumably the goldfish) (Abdoli, 2000; Teimori *et al*., 2010; Golchin Manshadi *et al*., 2012, 2014; Teimori *et al*., 2017); in the Sistan basin in the Hirmand and Sistan rivers, Hamun Kushk, the Sistan Dam and the Chahnimeh Reservoirs as well as throughout the hamuns (Ahmadi and Wossughi, 1988; Mansoori, 1994; J. Holčík, *in litt*., 1996; Shamsi *et al*., 2009; Latfi *et al*., 2018; my field work 1977); in the Tigris River basin throughout Khuzestan where now common (N. Najafpour and M. Al-Mukhtar, pers. comm., 1995; my field work 2000, absent in 1970s), in the Abshine, Beheshtabad (as *C. auratus gibelio* or *C. gibelio*), Beshar (as *C. auratus* and *C. gibelio*), Chardavol, Dez, Dinorab (as *C. carassius* ), Dinvar, Eberu-Simin, Ekbatan,

Gamasiab, Garavand, Gaveh (as *C. carassius*), Haramabad, Jarrahi, Kahman, Kahnak, Karkheh, Karun, Khorram (Khorramabad) as *C. carassius*, Mah, Marun, Qarasu (= Qareh Su), Qeshlaq, Razavar (= Raz Avar), Shur, Sirvan and Zab (as *C. carassius*) rivers, the Agh-Gol, Bisheh-Dalan, Gamasiab, Hana, Haramabad, Khondab, Pir Salman and Shadegan wetlands, the Choghakor (= Chagha Khur) Lagoon (as both *C. auratus* and *C. gibelio*), Lake Zaribar (as both *C. auratus* and *C. gibelio*), the Azad (as *C. gibelio*), Dez and Qeshlaq dams, and Yavari Spring, Kermanshah (Fadaei Fard *et al*., 2001; Eskandari *et al*., 2007; Sadeghinejade Masouleh, 2008; Abbasi *et al*., 2009; Shamsi *et al*., 2009; Raissy *et al*., 2010; Ansari and Raissy (2011); Esmaeili and Gholamifard, 2011; Bahrami Kamangar *et al*., 2012a; Eagderi and Nasri, 2012; Jalali *et al*., 2012; Esmaeili *et al*., 2013; Reyahi-Khoram *et al*., 2014; Yahyazadeh *et al*., 2014b; Zare *et al*., 2014a; Taghavi Niya and Velayatzadeh, 2015; Alizadeh Marzenaki *et al*., 2016; Jouladeh-Roudbar *et al*., 2016, 2020; Taghiyan *et al*., 2016; Mirzergar and Kulivand, 2017; Pourgholami Moghaddam *et al*., 2017; Fazli *et al*., 2018; Fatemi *et al*., 2019; Hasankhani *et al*., 2019; Nasri, 2021).

Also found in Chitgar Lake, an artificial water body in northwest Tehran where identified as *C. auratus, C. gibelio* and *C. carassius* (Bagheri *et al*., 2016; Ramin *et al*., 2016; Ramin and Doustdar, 2017b).

Goldfish are also recorded from the Karakum Canal and Kopetdag Reservoir in Turkmenistan (Shakirova and Sukhanova, 1994; Sal'nikov, 1995) and may eventually reach Iranian waters from this source in the Tedzhen (= Hari) River basin.

The Prussian carp (*C. gibelio*) is less widely distributed and its presence and distribution in Iran are not known. It is widely distributed in Turkey according to Özcan (2007) and Yerli *et al*. (2014) and is also reported from southern Iraq (Jawad *et al*., 2012) if correctly identified.

**Zoogeography.** This species was introduced to Iran, presumably multiple times. Some are undoubtedly aquaculture pond escapees or aquarium releases. Goldfish are kept in aquaria as part of the Now Ruz (New Year) celebrations in March each year. Tehran television (and the Green Front of Iran, see below) urged people to release them into local waters rather than killing them after the New Year (J. Valiallahi, pers. comm., 2000).

**Habitat.** This species is found in rivers, streams, lakes, dams, lagoons, ponds, marshes, springs and qanats, as well as artificial water bodies.

*Carassius auratus*, Kerman, Ganjali Khan Hammam
(ponds and fish …. in Farsi, cropped, CC BY-SA 4.0, Hossein Zamani).

Goldfish are hardy and can live in winterkill water bodies with much aquatic vegetation, low oxygen, and high pollution (Gudkov, 1985). They can also survive several hours out of water (Pelz, 1987) and may bury themselves in mud, albeit temporarily when scared (Szczerbowski in Bănărescu and Paepke, 2002). Goldfish up to 40.0 cm length died in a lake in Park-e Shahr, Shiraz on 30 May 1976, possibly from oxygen depletion at night, algal toxins, or algae clogging gills. Goldfish appear to favour ponds or pools in streams with aquatic vegetation but often are introduced into small bodies of water as ornamental fish. They are tolerant of turbidity, e.g., clay at 225,000 mg/l, pH from 4.5 to 10.5, very high temperatures (upper lethal limit 41.4°C), and high salinity (17‰). This species was killed under experimental conditions, when gradually acclimated to increasing salinity at 28,200 μmho and, by sudden exposure, at 19,200 μmho (Jasim, 1988). This is a greater tolerance than that shown by *Cyprinus carpio*, another exotic introduced to Iran. However, *Carassius auratus* appeared in the Basrah fish market when an increase in the Tigris River discharge reduced the salinity of the Shatt al Arab (N. A. Hussain, *in litt*., 1994). It is the dominant cyprinoid numerically in the Shatt al Arab, Iraq although it only appeared there first in the 1990s (Mohamed *et al*., 2012; Mohamed and Hameed, 2019).

Hatton *et al*. (2018) listed various mean parameters for this species such as the upper incipient lethal temperature (38°C), critical thermal maximum (36.5°C), critical thermal minimum (0.7°C), optimal growth temperature (26.6°C), final temperature preferendum

(26.9°C), optimal spawning temperature (20.5°C), and optimal egg development temperature (24°C).

In Iran, it is one of two most abundant species in Caspian wetland areas along with *Gambusia holbrooki* (eastern mosquitofish) (*Iranian Fisheries Research and Training Organization Newsletter*, 19:4, 1998). Abbasi *et al*. (2009) in their study of wetlands in Hamadan Province found this species was the second most dominant out of 23 species at 12.5%. Sadeghinejad Masouleh (2021) found *C. gibelio* in all stations and in all seasons in the Anzali Wetland.

**Age and growth.** Data in this section is grouped roughly by area.

In the Anzali Talab, Holčík and Oláh (1992) found only 6 age groups (as did Bagirova *et al*. (1990) in reservoirs of Azerbaijan while Pipoyan and Rukhkyan (1998) found 9 age groups in Armenia) with the largest fish 32.0 cm standard length owing to intense fishing pressure. Growth in mm increments was successively 93, 47, 50, 42, 28, and 37. The population was entirely female (see below). Individual life span was greater in Armenia where males were scarce or absent than in bisexual populations (Pipoyan and Rukhkyan, 1998). Sayad Borani *et al*. (2001) studied this species (identified as *C. a. gibelio*) in the Anzali Talab at four localities and found a mean fork length of 19.5 cm (range 2.5-31.5 cm) and a mean weight of 196.8 g. The mean age was 2.6 years. The mean length, weight and age were higher in the Siahkeshim area of the lagoon. The exploitation rate was 0.47, $L_\infty$ was 36.0 cm and K was 0.23 per year. Moradinasab *et al*. (2012) found 95 Anzali Wetland or Talab fish identified as *C. a. gibelio*, 11.3-35.3 cm total length, to have a *b* value in the length-weight relationship of 2.8791, negatively allometric, a relative condition factor of 1.01 and a Fulton’s condition factor of 1.55. Abbasi *et al*. (2017) examined 64 fish from the Anzali Wetland and found fish up to age 7. MoradiChafi *et al*. (2018) studied 100 males (6.4-28.7 cm, mean 12.8 cm total length; for 29 fish age was 1-5 years old) and 676 females (4.8-33.2 cm, mean 13.5 cm; for 190 fish age was 1-10 years) from the Anzali Wetland, identified as *C. gibelio*. Adult males and females formed 12.9% and 87.15% of adults. Sadeghinejad Masouleh (2021) found a sex ratio between males and females in *C. gibelio* from the Anzali Wetland was 1:11 and their age ranged from 1 to 5 years. The maximum total length was 31.5 cm in a fish with 621 g weight.

Esmaeili and Ebrahimi (2006) gave a *b* value of 2.91 based on 41 Iranian fish measuring 5.65-8.17 cm standard length. Niazie *et al*. (2013) found that with increased stocking density growth was significantly affected but not survival or condition factor.

Patimar (2009) examined 1,450 fish from the Alma-Gol (= Ulmogol) and Alagol wetlands in Golestan from 2000 to 2002. Ages ranged from $0^+$ to $8^+$ with negative allometric growth in Ulmogol, and positive allometric growth in Alagol. The von Bertalanffy growth curves for mean total lengths were $L_{tmales} = 183.33(1-e^{-0.31(t+1.05)})$ and $L_{tfemales} = 245.66(1-e^{-0.19(t+1.21)})$ for Ulmogol and $L_{tmales} = 224.79(1-e^{-0.24(t+0.83)})$ and $L_{tfemales} = 242.80(1-e^{-0.23(t+0.80)})$ for Alagol. The sex ratio was unbalanced for male:female at 1:1 and 1:12.7 for Ulmogol and Alagol respectively because of gynogenesis. Bagheri *et al*. (2010) examined 49 fish from the Gorgan River estuary and found age groups $1^+$ to $3^+$ years, the moment growth coefficient between age groups was 0.57 and 0.32 respectively, and growth was positively allometric. Ahmadi *et al*. (2013) gave length-weight relationships for 37 Alagol and 30 Sefid River fish as $W = 0.0002TL^{2.2488}$ and $W = 0.00002TL^{2.7799}$, showing that fish could adapt to different environmental conditions and habitats. Hajirad Kochak *et al*. (2016) and Hajiradkochak *et al*. (2016) examined 238 fish, 4.3-19.6 cm total length, in the Alakoli Reservoir, Golestan (identified as *C. gibelio*) and found maximum length was 19.6 cm for females and 19.0 cm for

males, and maximum weight was 114.65 g for females and 98.64 g for males, the male:female sex ratio was 1:10.9, the length-weight relationship was $W = 0.013TL^{3.08}$ for females (positive isometric) and $W = 0.016TL^{2.95}$ for males (isometric) and $W = 0.013TL^{3.07}$ for sexes combined, and the condition factor was 1.65 in males, 1.3 in females and 1.32 combined. Hajiradkochak *et al*. (2016) found 222 fish from Boostan Dam, Golestan had a maximum total length of 20.6 cm for females and 12.6 cm for males and maximum weight 141.1 g for females and 33.9 g for males. Sex ratio was 1:7.88 in favour of females. Ghojoghi *et al*. (2017) investigated some growth parameters of fish identified as *C. gibelio* in the bony fish culture reservoirs of Sijaval, southeastern Caspian Sea, based on 198 specimens caught from May to September 2016. The sex ratio was 1:15.5 in favour of females. The ranges of the lengths and weights were 6.8-24.3 cm and 8.676-254.857 g. The length-weight relationships for females and males were $W = 0.042TL^{2.6704}$ and $W = 0.045TL^{3.49}$ respectively, indicating a negative allometric growth pattern for females and positive allometric growth pattern for males. The population included 4 age groups ranging from $1^+$ to $4^+$. The mean of the Fulton condition factor was calculated at 1.88 for females and 1.55 for males. The von Bertalanffy parameters were $L_\infty = 30.29$, k = 0.18 and $t_0 = -0.577$. Hajiradkouchak *et al*. (2019) collected 942 specimens identified as *C. gibelio* from the Alakoli, Boostan, Golestan and Voshmgir dams in the southeast Caspian Sea. The largest fish was 22.0 cm total length and 139.8 g from Voshmgir. The condition factor increased markedly at all sites during late April-August. Growth was positively allometric in females from Alakoli and negatively allometric in females from Boostan, Golestan and Voshmgir. Growth was negatively allometric in males from Voshmgir and isometric at other sites. von Bertalanffy growth parameters were $L_\infty = 34.8$ cm, K = 0.04, $t_0 = -0.12$ yr for females, $L_\infty = 53.1$ cm, K = 0.01, $t_0 = -0.18$ yr for males and $L_\infty = 47.8$ cm, K = 0.01, $t_0 = -0.4$ yr for the population in Alakoli, $L_\infty = 29.9$ cm, K = 0.18, $t_0 = -0.1$ yr for females, $L_\infty = 57.4$ cm, K = 0.07, $t_0 = -1.04$ yr for males and $L_\infty = 33.8$ cm, K = 0.15, $t_0 = -0.34$ yr for the population in Boostan, $L_\infty = 37.8$ cm, K = 0.12, $t_0 = -0.35$ yr for females, $L_\infty = 30.9$ cm, K = 0.17, $t_0 = -0.02$ yr for males and $L_\infty = 35.6$ cm, K = 0.13, $t_0 = -0.35$ yr for the population in Golestan, and $L_\infty = 29.6$ cm, K = 0.2, $t_0 = -0.2$ yr for females, $L_\infty = 18.6$ cm, K = 0.51, $t_0 = -0.42$ yr for males and $L_\infty = 30.3$ cm, K = 0.19, $t_0 = -0.18$ yr for the population in Voshmgir. Hajiradkouchak *et al*. (2020) studied fish identified as *C. gibelio* from the Boostan Dam Lake (222 fish) and from the Alakoli Reservoir (238 fish) (and compare with above). The sex ratio was 1:0.13 and 1:0.09 in the study population of Boostan Dam Lake and Alakoli Reservoir, respectively (sex not specified and only abstract available). Age determination by scales showed six age groups ($1^+$ to $6^+$) for females and three age groups ($1^+$ to $3^+$) for males in the Bostan Dam Lake and five age groups ($1^+$ to $5^+$) for females and four age groups $1^+$, $2^+$, $4^+$ and $5^+$ for males in the Alakoli Reservoir. The total size distribution varied from 3.3 to 20.6 cm in length and 0.83 to 141.12 g in weight and from 4.3 to 19.6 cm in length and 1.67 to 114.65 g in weight in the Boostan Dam Lake and Alakoli reservoir respectively. The growth pattern was isometric in males and negative allometric for both females and population in the Boostan Dam Lake and isometric in males and positive allometric for both females and population in the Alakoli Reservoir. The parameters of von Bertalanffy growth fit the mean observed total lengths-at-age for each sex separately and were estimated as $L_\infty = 574.17$ cm *(sic*, presumably mm here and below), k = 0.07/year, $t_0 = -0.10$/year for females, $L_\infty = 338.43$ cm, k = 0.15/year, $t_0 = -1.04$ year for males, and $L_\infty = 299.06$ cm, k = 0.18/year, $t_0 = -0.34$/year for combined sexes in the Boostan Dam, $L_\infty = 4344$ cm, k = 0.01/year, $t_0 = -0.12$/year for females, $L_\infty = 3177$ cm, k = 0.01/year, $t_0 = -0.18$ year for males, and $L_\infty = 2526.15$ cm, k = 0.04/year, $t_0 = -0.40$/year for combined sexes in the

Alakoli Reservoir. The instantaneous growth rate was $1^+$to $2^+$ ages for the population in both regions. The condition factor showed that in the Boostan Dam Lake, the highest value was observed in June and August for females and the lowest in March for males, and in the Alakoli Reservoir the highest condition factor was in May for females and the lowest in May for males. Differences with other studies could be attributed to environmental differences.

Moradi Chafi *et al*. (2016) found fish, 7.7-17.7 cm, identified as *C. gibelio* in Nur or Neor Lake, Ardabil Province were 2-3 years old, average age was 2.23 years and condition factor was 1.85. Pourgholami Moghaddam *et al*. (2018) also examined fish identified as *C. gibelio* from this lake and found age groups 1 to 5 years, $L_\infty$ = 37 cm, K = 14.0%, total mortality = 0.63, natural mortality = 0.22, fish mortality = 0.41, obesity coefficient = 0.0168 and biomass = 4.39 t.

Zare *et al*. (2014a) found a length-weight relationship for 167 Karkheh River fish of W = 1.9 + 3.32LogL indicating positive allometric growth and a condition factor of 0.96, similar to studies elsewhere. Fazli *et al*. (2017, 2018) examined 66 fish, 7.0-27.1 cm total length, identified as *C. gibelio* from Azad Dam Lake in Kordestan and found fish reached 404.0 g, had an age range of 1-6 years with age 2 dominant (30.3%) with rapid growth in the first two years of life, a length-weight regression of $W = 0.000003FL^{3.3537}$ indicating a positive allometric growth, a male:female sex ratio of 1:27.5, von Bertalanffy growth parameters were estimated as $L_\infty$ = 32.5 cm, $K$ = 0.28 yr$^{-1}$, $t_0$ = -0.20 yr (or the von Bertalanffy growth equation was $L_t = 33.7\ \mathrm{cm}(1-e^{-0.255(t-(-0.21))})$ in the 2018 version), the instantaneous coefficient of natural mortality was estimated as 0.51 yr$^{-1}$, the average condition factor was 1.68 with significant differences among seasons, the average relative condition factor was 0.88, at less than 1.0 suggesting that the fish condition and feeding activity were not good, and the growth performance (ø') was 2.47. Hashemi *et al*. (2019) collected samples from five stations of Shadegan Wetland, namely Atish, Doragh, Khorosy, Rogabe and Salmane and comprising 526 fish, length 10.6-32.2 cm. Mean length values for males and females were 16.4 cm (12.3-26.4 cm) and 19.8 cm (10.6-32.2 cm), respectively and mean weights were 81 g (23-308 g) and 148 g (18-650 g), respectively. The length-weight relation was calculated as $Y = 0.000008L^{3.13}$ for males and $Y = 0.000009L^{3.15}$ for females. The time of spawning was determined as April to November. Length at maturity ($L_M$), weight at maturity ($W_M$) and production per biomass ($P/B$) were calculated for total fish as 16.3 cm, 37 g and 0.74, respectively. $L_\infty$, $K$, $t_0$ were estimated to be 34.6 cm, 0.36 per year, and -0.23, respectively. Natural mortality, fishing, total, and exploitation coefficients were 0.75, 0.77, 1.52, and 0.51, respectively. Valikhani *et al*. (2020) combined fish from the Shadegan Wetland and the Dez and Karkheh rivers and reported a *b* value of 2.82 (isometric growth) and a condition factor of 2.01 for 6 fish (8.4-15.0 cm total length).

Radkhah and Eagderi (2015a) gave a *b* value for 25 fish identified as *C. gibelio* from the Zarrineh River, Lake Urmia basin, 3.4-21.4 cm total length, as 2.95, isometric growth. Condition factor was 1.041.

Paighambari *et al*. (2020) gave a *b* value of 3.09 for 16 fish (21.6-51.2 cm total length) identified as *C. gibelio* from the Dorudzan Dam, Fars.

Maturity was attained at 3-4 years in the Volga Delta. Life span was 13 years with most growth in the first 2-4 years to a size of 15-20 cm (Gudkov, 1985; Kizina, 1986). Life span in captivity in China may exceed 50 years. Population numbers in confined areas are limited by a chemical released by the goldfish which represses more spawning. Prussian carp (*C. gibelio*) live up to 11 years.

Mohamed *et al*. (2017) found 20,331 fish, 2.3-34.5 cm total length, in the East Hammar Marsh, Iraq had dominant length groups 11-21 cm, a *b* value of 3.085 (allometric growth), a maximum age of 6 years, $L_\infty$ = 41.5 cm. K = 0.26, male:female sex ratio 1:14.8, and a protracted spawning season. Abood and Mohamed (2020) found that *C. auratus* comprised 20.3% of the fish in the Shatt al Arab, Iraq which forms part of the border with Iran. They examined 1,511 pooled specimens from three sites with a length range of 4.0-26.8 cm total length. The bulk of the catch ranged from 12.0 to 16.0 cm, forming 67.5%. The length-weight relationship was $W = 0.0149L^{3.065}$, positive allometric growth. Growth parameters $L_\infty$, K and Ø were 29.1 cm, 0.51 and 2.635, respectively. The total (Z), natural (M) and fishing (F) mortalities were 2.69, 1.09 and 1.60, respectively. Exploitation rate (E) was 0.59. Length at first capture ($L_c$) was 10.04 cm. One main pulse of annual recruitment was displayed. The relative yield per recruit analysis revealed that the exploitation rate (E) of *C. auratus* was higher than the biological target reference points $E_{0.1}$ and equivalent to $E_{max}$. The *C. auratus* stock in the Shatt Al-Arab River was operating near the exploited situation and needed precautionary measures to avoid overexploitation such as preventing illegal fishing methods and execution of the closed season.

Sarı *et al*. (2008) examined 2,325 fish from Buldan Dam, Gediz River basin, Turkey (referred to as *C. gibelio*) which had a maximum age of 6 years and attained 25.5 cm and 269.1 g (Sarı *et al*., 2008). von Bertalanffy growth parameters were $L_\infty$ = 31.66 cm, $W_\infty$ = 635.91 g, k = 0.146 year$^{-1}$ and $t_0$ = -2.166 year. Ratios of total, natural and fishing mortality were calculated as 0.632 year$^{-1}$, 0.456 year$^{-1}$ and 0.176 year$^{-1}$.

**Food.** Food is predominately zooplankton but also includes aquatic insects, crustaceans, molluscs, worms, detritus, filamentous algae, macrophytes and young fish, switching from one kind of food to another as circumstances warrant. Goldfish have a palatal organ on the roof of the mouth used to taste and touch food and their dense gill rakers aid in feeding on smaller food items.

In Nur or Neor Lake, Ardabil Province, fish identified as *C. gibelio* fed on Chlorophyta, Bacillariophyta and Rotatoria in 100% of samples, on Euglenophyta in 80%, on Nematoda in 23.3% and Cladocera in 10% (Moradi Chafi *et al*., 2016). Abbasi *et al*. (2017, 2018) examined 64 fish (identified as *C. gibelio*) from the Anzali Wetland and found Tubificidae, Chironomidae, Lumbriculidae and Physidae from the macrobenthos, 45 genera from six phyla from the phytoplankton and 17 genera from seven phyla of the zooplankton in the gut contents. Bacillariophyta, Cyanophyta and Chlorophyta had 19, 7 and 13 genera, respectively and these phyla were observed in 95.4%, 73.9% and 63.1% of total specimens as main food items and were 70.76%, 20.56% and 8.02% of phytoplankton cells respectively. *Nitzschia*, *Cyclotella* and *Oscillatoria* genera were dominant in the gut with 34.69%, 12.11% and 10.02% of total numbers of phytoplankton cells respectively. Arthropoda, Rotatoria and Rhizopoda had five, five and three genera respectively and were observed in 52.9%, 55.9% and 26.5% of total studied specimens as the main or secondary food items and they constituted 34.11%, 33.86% and 26.79% of zooplankton prey. The genera *Centropyxis*, *Cyclops*, *Brachionus* and *Alona* were dominant in the gut with 22.39%, 19.05%, 12.35% and 11.09% of total numbers of zooplankton counts respectively. In general, this fish was a plankton-feeder and detritivore (mainly algae) and had little overlap in food items with *Cyprinus carpio*, a benthic omnivore (mainly animal origin).

In the recovering Hawr al Hammar, Iraq, diet was 46.1% algae and 25.5% diatoms, with amounts of plants, crustaceans, insects, snails and fish being less than 10% each, in the

Hawr al Hawizeh diet was 36.3% algae, 21.3% diatoms and 17.5% copepods, with amounts of plants, cladocerans, ostracods and insects being less than 10% each, in the Al Kaba'ish (= Chabaish) Marsh diet was 45.5% algae, 25.2% diatoms, with plants, various crustaceans, insects and snails at less than 10% each (Hussain *et al*., 2006). Mohamed and Abood (2018) found this species was a generalised feeder in the Shatt al Arab, Iraq and fed on aquatic insects (28.9%), macrophytes (26.2%), algae (12.8%), detritus (12.4%), zooplankton (6.0%), diatoms (5.8%) and snails (5.5%). The diet was close to that of native *Carasobarbus luteus* and these fish were in competition for food items in the Shatt al Arab River.

Özdelik and Jones (2014) examined the diet of fish identified as *C. gibelio* in the Karamenderes River, northwest Turkey. Filamentous algae were the most important components, other food items were macroinvertebrates, detritus and seston. This fish had a wider trophic niche width compared to native species, contributing to its success as an invasive species.

**Reproduction.** The fish in the Anzali Talab are all female, reproducing through gynogenesis. Sayad Borani *et al*. (2001) found fish in Anzali Talab to have a female:male sex ratio of 99.3:0.7. Egg development is stimulated by sperm, probably from *Cyprinus carpio*, *Tinca tinca*, *Blicca bjoerkna* or *Scardinius erythrophthalmus*. Here fish may mature at 1 year of age, and coupled with polycyclic ripening of eggs and intermittent spawning, this has led to the dominance of this species in the fresh waters of the lagoon (Holčík and Oláh, 1992). MoradiChafi *et al*. (2018) for Anzali Wetland or Talab fish found the monthly average of the gonadosomatic index was 1.52% in September and 9.82% in April with an annual average of 5.17 for adult females. The spawning period determined on the basis of the gonadosomatic index and gonad maturity stages of adult females was from April to September. Absolute fecundity of 21 fish was 1,215-141,314 eggs with an average of 27,453.2 eggs. Spawning began in late April to mid-May in the Volga Delta and occurred in May-June in the Anzali Talab (Sayad Borani *et al*., 2001). Eggs were laid in 2-5 batches over a spawning period extending into July. Up to 10 batches were laid elsewhere at 8-10 day intervals with up to 4,000 greenish-yellow eggs in each batch. Fecundity reached 253,200 eggs (elsewhere to 685,700 with absolute fecundity reaching 860,000 eggs). The largest eggs were 1.6 mm in diameter (Gudkov, 1985; Kizina, 1986; Szczerbowski in Bănărescu and Paepke, 2002). Each female was accompanied by two or more males, and chases were reported with splashing and shooting through the water near the surface. The eggs are adhesive and attach to water plants and hatch in 5-8 days.

Patimar (2009) examined fish from the Alma-Gol (= Ulmogol) and Alagol wetlands and found reproduction in February, March and April. Absolute fecundity reached 13,020 eggs. Gorgan River fish sampled by Bagheri *et al*. (2010) were all female. Hajirad Kochak *et al*. (2016a) examined fish in the Voshmgir Dam, Golestan (identified as *C. gibelio*) and found the highest average gonadosomatic index was in June for both sexes, sex ratio was 1:10.56 (presumably in favour of females), maximum fecundity and mean absolute fecundity were 430,416 and 65,270 eggs, average relative fecundity was 1,283 eggs/kg, and mean diameter of eggs was 0.62 mm with a maximum of 1.11 mm. Hajirad Kochak *et al*. (2016b) examined fish in the Golestan Dam (identified as *C. gibelio*) and found the highest average gonadosomatic index in June for females and May for males, the sex ratio was 1:10.23 (presumably in favour of females), maximum fecundity and mean absolute fecundity were 83,134 and 13,272 eggs, average relative fecundity was 1,002 eggs/kg, and mean diameter of eggs was 0.64 mm with a maximum of 1.39 mm. Hajiradkochak *et al*. (2016) found fish from Boostan Dam, Golestan

had the highest average gonadosomatic index for females in April (10.27) and for males in March (3.56), the minimum, maximum and mean absolute fecundities were 532.08, 82,039.36 and 13,119.44 eggs respectively, the minimum, maximum and mean relative fecundities were 37.54, 4,344.34 and 593.1 eggs/kg, and egg diameters were 0.11-1.00, mean 0.56 mm. Fish from the Alakoli Dam, Golestan had the highest average gonadosomatic index for females in March (11.73) and for males in May (3.22), the minimum, maximum and mean absolute fecundities were 1,503.75, 120,786.0 and 23,174.6 eggs respectively, the minimum, maximum and mean relative fecundities were 92.97, 23,377.2 and 1,987.6 eggs/kg, and egg diameters were 0.11-1.07, mean 0.54 mm. Hajiradkouchak *et al*. (2019) examined fish from dams on the southeast Caspian Sea and found a prolonged spawning season from April through August, and a maximum eggs diameter and absolute fecundity of 1.39 mm and 72,865 eggs in Voshmgir Dam. Hjrad Koochak (*sic*) *et al*. (2020) examined 247 specimens from the Golestan Dam and 208 specimens from the Voshmgir Dam identified as *C. gibelio* and found a sex ratio of 1:10.23 and 1:10.56 respectively (presumably in favour of females). The highest average gonadosomatic index in the Golestan Dam for females and males was in June and May, respectively, at 12.2 and 3.8 for females and males respectively, and in the Voshmgir Dam for both females and males was observed in June at 11.15 and 2.93 for females and males respectively. The maximum total length and weight of Golestan Dam females and males were 196.0 mm and 141.35 g and 156.0 mm and 52.42 g and in the Voshmgir Dam for females and males were 240.0 mm and 280.6 g and 179.0 mm and 81.75 g. Minimum, maximum and mean absolute fecundities in the Golestan Dam were 327.71, 83,134.09 and 13,272.67 and in the Voshmgir Dam were 4,857.82, 65,270.02 and 43,0416.0. Minimum, maximum and average relative fecundities (eggs/kg body weight) were in the Golestan Dam 147.93, 5,432.02 and 1,002.48 and in the Voshmgir Dam were 100.94, 10,722.34 and 1,283.99. The mean diameter of eggs in the Golestan Dam was 0.64 mm, range 0.11-1.39 and in the Voshmgir Dam was 0.62 mm, range 0.13-1.11.

In Armenia, maturity appeared to be linked with average annual temperature. At 12.0-13.1°C it occurred at the end of the first year of life while at 8.4-9.0°C it occurred at the end of the third and fourth years (Pipoyan and Rukhkyan, 1998). Turkish populations in Topçam Dam, Aydın (Şaşı, 2008) and Buldan Dam, Gediz River basin (Sarı *et al*., 2008) referred to *C. gibelio* were 98.84% and 99.44% female. Spawning in the former locality was from March to August, suggesting multiple spawnings with mean fecundity ranging from 37,823 in August to 85,159 in March. Egg diameter reached 1.099 mm in June.

Parasites and predators. This species has been widely examined for parasites, both in natural habitats and in aquarium fish in Iran. It is readily available from aquarium suppliers. The grouping of studies below by decades shows the growth in research.

Mokhayer (1976b) recorded infectious dropsy and gas bladder inflammation in Iranian goldfish. Saprolegniosis was reported from goldfish in Iran (Rahbari and Razavilar, 1982), where growths of the fungus *Saprolegnia parasitica* resembled tufts of cotton wool. Mokhayer (1989) reported metacercariae of the eye fluke, *Diplostomum spathaceum*, which could cause complete blindness and death in commercially important species. Jalali and Molnár (1990a) recorded the monogeneans *Dactylogyrus baueri*, *D. extensus*, *D. formosus* and *D. vastator* from fish in the Sefid River. Jalali and Molnár (1990b) reported a variety of monogeneans variously in fish farms throughout Iran, namely *Dactylogyrus baueri*, *D. dulkeiti*, *D. formosus*, *D. vastator* and *D. vastator* forma *minor*. Molnár and Jalali (1992) recorded the monogenean *Dactylogyrus intermedius* and Gussev *et al*. (1993a) described a new species of monogenean,

*Dactylogyrus intermedioides*, from goldfish on fish farms near Tehran. Shamsi *et al*. (1997) reported *Clinostomum complanatum*, a parasite causing laryngo-pharyngitis in humans.

The helminth *Anisakis* sp. was recorded from the guts of this species in the Anzali Wetland (Ataee and Eslami, 1999; www.mondialvet99.com, downloaded 31 May 2000). Mousavi (2003) recorded the monogeneans *Dactylogyrus baueri*, *D. extensus*, *Gyrodactylus kobayashii*, *Gyrodactylus* sp., *Trichodina* sp., the ciliates *Ichthyophthirius multifilis* and *Ichthyoboda* sp. and the copepods *Argulus foliaceus* and *Lernaea cyprinacea* from ornamental fish. Naem *et al*. (2002) found the following parasites on the gills of fish from the western branch of the Sefid River, namely the protozoans *Ichthyophthirius multifilis* and a *Trichodina* species, and monogenean trematodes *Dactylogyrus anchoratum* and *Gyrodactylus* sp. Jalali *et al*. (2002) and Jalali and Barzegar (2006) recorded *Diplostomum spathaceum* from Lake Zaribar fish, Naem (2002) the monogenean *Dactylogyrus anchoratus* from fish in Sefid River and Mehdipoor *et al*. (2004) the monogenean *Dactylogyrus baueri* in fish in the Zayandeh River. Masoumian *et al*. (2005) recorded the protozoan parasite *Ichthyophthirius multifilis* from fish identified as *C. carassius*, presumably goldfish, in the Aras Dam in West Azarbayjan. Jalali *et al*. (2005) summarised the occurrence of *Gyrodactylus* species in Iran and recorded *G. kobayashii* and *G*. sp. in fish from the Sefid River. Khara *et al*. (2006a) recorded the eye fluke *Diplostomum spathaceum* for this fish in the Amirkelayeh Wetland and Khara *et al*. (2008) in fish from Boojagh Kiashahr Wetland, both in Gilan. Sattari *et al*. (2004, 2005) surveyed this species (as *C. carassius*) in the Anzali Wetland, recording *Raphidascaris acus* (and larvae), *Eustrongyloides excisus* and *Camallanus lacustris*. Masoumian (2007) reported the parasite *Diplozoon megan* from fishes identified as *Carassius carassius* (probably *C. auratus*) in the Aras, Ghotor and Zangbar rivers in West Azarbayjan. Pazooki *et al*. (2007) recorded various parasites from localities in West Azarbayjan Province, and found *Eustrongyloides excisus*. Sattari *et al*. (2007) reported the nematode *Raphidascaris acus*, the digenean *Diplostomum spathaceum* and the monogeneans *Dactylogyrus extensus* and *Gyrodactylus* sp. in this species in the Anzali Wetland. Barzegar *et al*. (2008) recorded the digenean eye parasites *Diplostomum spathaceum* and *Tylodelphys clavata*. Shamsi *et al*. (2009) found *Dactylogyrus baueri*, *D. dulkeiti*, *D. extensus*, *D. intermedius*, *D. intermedioides* and *D. wegeneri* from localities such as fish farms, the Sefid River, Zayandeh River, Lake Zaribar and the Hamun Lake. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Lernaea* sp. on this species.

Fadaeifard *et al*. (2010) examined farmed fish (identified as *Carassius carassius* but referred to as goldfish) for ectoparasites and found *Trichodina* sp., *Gyrodactylus* sp., *Dactylogyrus baueri* and *Dactylogyrus* sp. Mood *et al*. (2010) found metacercariae of the trematode *Centrocestus formosanus* on goldfish imported from Southeast Asia. Rahmati-holasoo and Ebrahimzadeh Mousavi (2011) recorded earlier infestations of goldfish in Iran with this parasite. Ebrahimzadeh Mousavi *et al*. (2011) collected 1,200 fish from 10 ornamental fish farms in different areas of Iran and recorded the fish lice *Argulus coregoni*, *A. foliaceus* and *A. japonicus* along with *Gyrodactylus* spp., *Dactylogyrus* spp., *Trichodina* spp. and *Ichthyophthirius multifilis*. Quarantine of ornamental fish was recommended. Khara *et al*. (2011) listed the monogenean *Dactylogyrus* sp. from fish in the Boojagh Wetland of the Caspian Sea. The noted uncontrolled import of live fish, and their parasites, could cause a serious loss of native fishes. Mohzdeganlou *et al*. (2011) were able to detect the monogeneans *Dactylogyrus dulkeiti* and *D. vastator* from gills of goldfish bought in Tehran pet stores using DNA alone. Even a single parasite could be detected and this technique was advocated as

faster and less technically difficult than microscopic detection and identification. This is important in health quality control of imported fish species. Tavakol *et al*. (2011) studied occurrence and distribution of the bacteria *Aeromonas* spp. in farmed goldfish in Gilan, meant for the Now Ruz (New Year holiday) trade. This bacterium could cause diarrhoea in humans, especially children, and is prevalent in crowded conditions. Bahri *et al*. (2012) studied goldfish from aquaria in Tehran, a matter of concern for transmission of parasites. Parasites found were *Microsporidia* sp., *Trichodina* sp., *Ichthyophthirius multifilis*, *Dactylogyrus* sp. and *Gyrodactylus* sp. Golchin Manshadi *et al*. (2012) and Golchin Manshadi (2018) found *Ichthyophthirius multifilis*, *Dactylogyrus anchoratus* and *Gyrodactylus* sp. in this species (identified as *C. carassius* but assumed to be goldfish) in Lake Parishan. Notash (2012) found 28.33% of goldfish in Azarbayjan fish markets carried the fish louse *Argulus*. Ebrahimzadeh Mousavi *et al*. (2012) identified *Gyrodactylus gurleyi* on ornamental fish using molecular and morphometric methods. Rasouli *et al*. (2012) listed various ectoparasites from *C. carassius* (probably *C. auratus*) in waters of West Azarbayjan namely *Diplostomum spathaceum*, *Dactylogyrus* sp., *Gyrodactylus* sp., *Trichodina* sp., *Ichthyophthirius multifilis*, *Argulus* sp. and *Chilodonella* sp. Rasuli *et al*. (2012) recorded the eye parasite *Diplostomum spathaceum* from fish (identified as *Carassius carassius*) in the Nazlu Chay at Urmia, at a relatively high level of 16.3%. Raissy *et al*. (2009, 2013) reported on a parasitic outbreak of *Lernaea cyprinacea* in the Choghakhor (= Chagha Khur) Lagoon, Chahar Mahall and Bakhtiari Province. Khodadadi *et al*. (2013) examined ornamental goldfish from breeding centres in Urmia City finding 56.5% were contaminated with parasites, principally *Ichthyophthirius multifilis*, followed by *Dactylogyrus* spp. and *Trichodina* spp. with other parasites being *Gyrodactylus* spp., *Diplostomum spathaceum*, *Diplozoon* sp. and *Argulus foliaceus*. Rasouli (2013) found the digenean *Diplostomum spathaceum* in fish (identified as *C. carassius*) from Caspian drainages in West Azarbayjan. This parasite causes secondary infections as the metacercariae penetrate the skin and eye, lesions, appetite loss, blurry vision and reduced feeding. Shohreh *et al*. (2013) surveyed ectoparasites from ornamental fish supply centres in Mazandaran and found *Ichthyophthirius multifilis*, *Trichodina* spp., *Gyrodactylus* spp., *Dactylogyrus vastator*, *D. baueri* and *Argulus coregoni*, and advocated bio-security measures. Daghigh Roohi *et al*. (2014) and Daghigh Roohi (2016) reported on the occurrence of parasites in fish (identified as *C. gibelio*) from the Anzali Wetland, finding the protozoans *Ichthyophthirius multifilis* and *Trichodina* sp., the nematode *Raphidascaris acus*, the trematode *Diplostomum spathaceum*, the monogeneans *Dactylogyrus arquatus*, *D. baueri*, *D. dulkeiti*, *D. formosus*, *D. inexpectatus* and *Gyrodactylus kobayashii*, and the crustacean *Lernaea cyprinacea* in its copepodid stage. Mozhdeganloo and Heidarpour (2014) investigated the oxidative stress on gill tissues of fish parasitized by *Dactylogyrus* spp., and found severe stress and gill damage. Adel *et al*. (2015) found *Dactylogyrus* sp., *Gyrodactylus* sp., *Ichthyophthirius multifilis*, *Trichodina reticulata* and *Lernaea cyprinacea* from goldfish sampled from ornamental fish farms in Mazandaran. Mirzaei and Khovand (2015) found the crustacean *Argulus foliaceus* on ornamental goldfish in Kerman and noted it could be a risk factor for natural ecosystems. Rasuli and Pourghasem (2015) examined fish identified as *C. carassius* from the Zarrineh River in the Lake Urmia basin and found *Lernaea sp.* Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Pallisentis cholodkowskyi* in fish identified as *Carassius carassius* in the Zayandeh River Dam. Daghigh Roohi *et al*. (2016) examined specimens from fish ponds in Gilan and found the protozoans *Ichthyophthirius multifilis* and *Trichodina* sp., the digenean *Diplostomum spathaceum*, the monogeneans *Dactylogyrus anchoratus*, *D. baueri*, *D. formosus*, *D. vastator*

and *Gyrodactylus* sp., the copepodid stage of the crustacean *Lernaea cyprinacea* and a nematode larva. Sayyadzadeh *et al*. (2016) found the anchor worm *Lernaea cyprinacea* in fish from the Kor River basin where it has also spread to native species, presumably from this introduced species or introduced *Cyprinus carpio*. Moshaverinia *et al*. (2016) found several *Argulus* species in fish in Mashhad pet stores. Omidzahir *et al*. (2016) confirmed the identity of the monogenean *Gyrodactylus kobayashii* on goldfish using morphological and molecular techniques. Asgharnia *et al*. (2017a) identified three species of *Dactylogyrus* from gills, *Diplostomum spathaceum* from the eye lens, one species of *Gyrodactylus sp.* from the skin and *Trichodina sp.* and *Ichthyophthirius multifilis* from gills of fish identified as *C. carassius* from farm ponds in Gilan. Asgharnia *et al*. (2017b) found a prevalence rate for *Ligula intestinalis* of 30% in fish identified as *C. carassius gibelio* from western Iran. This parasite causes reduction in growth of reproductive glands, sterility and decline of fish reproduction potency by pressing on the reproductive organs. Golchin Manshadi (2017) reported *Dactylogyrus anchoratus*, *Gyrodactylus* sp. and *Ichthyophthirius* sp. from fish identifed as *C. carassius* in Lake Parishan, Fars. Hosseini Fard *et al*. (2017) examined fish identified as *C. carassius* from Babol and found 89.04% of fish were infected with such parasites as *Trichodina*, *Dactylogyrus*, *Gyrodactylus*, *Diplostomum spathaceum*, *Rhabdochona fortunatowi* and nematodes. Moeini Jazani *et al*. (2017) examined farmed fish for monogenean parasites and found an *Ancylodiscoides* sp., *Dactylogyrus baeri*, *D. formosus*, *D. vastator*, *Dactylogyrus* sp., *Gyrodactylus gurleyi*, *G. kobayashii*, *G. longoacuminatus* and *Gyrodactylus* sp. Rasouli *et al*. (2017) found a contamination of 23.33% for *Diplostomum spathaceum* in Shaharchay Dam Lake, Urmia for fish identified as *Carassius carassius*, this level being higher than acceptable by international standards. Barzegar *et al*. (2018) reported the monogenean *Gyrodactylus sprostonae* from fish identified as *C. gibelio* from the Babol, Tajan and Talar rivers in Mazandaran. Faeed *et al*. (2018) studied carp and the water in Gilan fish farms and found the zoonotic bacteria Enterobacteriaceae, *Pseudomonas* sp. (highest abundance), *Aeromonas* sp., *Streptococcus* sp. (lowest abundance), *Vibrio* sp. and *Mycobacterium* sp. Hosseinpour *et al*. (2018) found that 46.66% of goldfish from aquarium shops in Semnan were contaminated with mycobacteriosis or fish tuberculosis. Nassiri *et al*. (2018) found that ornamental goldfish had the highest infection rate of eight aquarium species examined, related to skin, gill and external parasites. The highest rate for external parasites was from farms that used well water. Rahmati-Holasoo *et al*. (2018) examined *C. auratus* from the production and distribution centres of ornamental fish in Karaj City for external parasites and found *Ichthyophthirius multifiliis* (8%), Trichodinidae (10%), Gyrodactylidae (8%), Dactylogyridae on gills (3%), Oodiniaceae (1%) and *Peritrichous* ciliates (1%). Alinejad and Shoaibi Omrani (2019) examined goldfish imported to Iran for external parasites and found 32% were free of parasites while the rest had protozoans (*Trichodina* sp. and *Ichthyophthirius multifilis*) and monogeneans (*Dactylogyrus baueri*, *D. formosus* and *Gyrodactylus* sp.).

Mirhashemi Nasab *et al*. (2020) investigated fish identified as *C. gibelio* from Nur or Neor Lake and found the monogenean trematode *Dactylogyrus anchoratus* on the gills, a possible source of contamination for aquaculture there. Moumeni *et al*. (2020) recorded the zoonotic *Centrocestus formosanus* from this fish in Iran.

Ebrahimzadeh Mousavi and Khosravi (2004) reported suspected epizootic ulcerative syndrome from ulcerated goldfish. Rezaie *et al*. (2017) described a fibrosarcoma in a moribund goldfish, a rare occurrence in fish generally and the first report from Iran for a goldfish.

Afsari *et al*. (2014) found human bacterial pathogens (*Pseudomonas mendosina* and

*Aeromonas* spp.) on fish from Iranian aquaculture ponds, confirmed by gene sequencing.

Oladi *et al*. (2016) noted eye-attacking behaviour of koi carp on goldfish on a polyculture carp farm in Tabriz. Both eyes were removed from 45 goldfish and no eyes were found in the concrete tanks.

*Silurus glanis* (European catfish) eats this species in the Boojagh Wetland in the spring (Ershad Langroudi *et al*., 2017). Barati *et al*. (2008) found pygmy cormorants (*Phalacrocorax* (= *Microcarbo*) *pygmaeus*) chicks ate this species (identified as *C*. *carassius*) in the Siahkeshim Protected Area of the Anzali Wetland. Ashoori (2010) recorded that little egret chicks (*Egretta garzetta*) in the Karfestan Ab-bandan, Rudsar, Gilan were fed this species (identified as *C*. *gibelio*) by adults. Ashoori *et al*. (2012) found that grey herons (*Ardea cinerea*) in the Siahkeshim Protected Area ate this species (identified as *C. carassius*) predominately. Ashoori *et al*. (2017a) recorded fish, identified as *C*. *gibelio*, were dominant in the diet of young black-crowned night herons (*Nycticorax nycticorax*) in the Anzali Wetland. Mirzajani *et al*. (2021) found the Eurasian otter (*Lutra lutra*) ate this fish identified as *C*. *gibelio* preponderately in the Anzali Wetland.

Economic importance. This species is raised on Tehran and Gilan fish farms for the pet trade (Molnár and Jalali, 1992; Tavakol *et al*., 2011) as well as elsewhere in Iran. Seidgar *et al*. (2015) and Seidgar (2016) found that frozen fairy shrimps (*Phallocryptus spinosa*) were a suitable replacement for *Artemia urmiana* to enhance colour of these ornamental fish.

This species forms part of the Now Ruz (= New Year, usually 21 March) celebrations in Iran where a bowl with goldfish is part of the traditional Haft Sin table setting (so called for seven items that must be present, all beginning with the letter S, each having a symbolic meaning, the goldfish is in addition to these). The goldfish in a bowl represents life within life, and the sign of Pisces which the sun is leaving. Ghazilou and Elder (2015) stated that it might represent saying goodbye to the previous year, the legendary *kara* fish of ancient Iranian mythology that wards off harmful creatures on the last day of the year, or a misunderstanding of Chinese New Year custom of releasing goldfish as a symbolic return to nature (goldfish were first imported to Iran from China in the 1930s). Live goldfish have been replaced by plastic ones or an orange in recent years as animal rights activists have pointed out that most fish die when released into the wild after Now Ruz. President Rouhani's Twitter account showed an orange in 2016 (BBC Monitoring 21 March 2016).

Now Ruz goldfish in Tehran (CC BY-SA 2.0, Ninara).

Haft Sin Table, Iranian Embassy, Ottawa, 2009, Brian W. Coad.

Aquarium goldfish at Iranian Embassy, Ottawa, 2009, Brian W. Coad.

In the Anzali Talab, 62% of the total catch is goldfish, an accidental introduction (Petr, 1987). Catches in gill nets there are dominated by this species at 38% (Moradinasab *et al*., 2012). The catch in the talab in 1990 was 46,472 kg (Holčík and Oláh, 1992). As the salinity of this lagoon increases, the density of goldfish will decrease. Valeipour and Haghighy (2000) recorded the catch for 1992-1996 at 40% of the species taken. Safaee (2005) gave a goldfish catch figure of 45% of the 313 ton fishery there in 1992. The presence of goldfish in the Anzali Talab led to a decline in the native fishery there.

This species is caught by anglers at Ahvaz in Khuzestan using bread or potato as bait (personal observations, 2000).

Goldfish appear on Iranian stamps, for example below, and see also under **History of Research**:-


*Carassius auratus* stamp, Brian W. Coad.


*Carassius auratus* stamp, Brian W. Coad.

The peculiar type of reproduction is very successful and affects the catches of other cyprinoid species, being equivalent to a predatory effect (Holčík and Oláh, 1992). There is some evidence that this fish disturbs the habitat of native species, muddying waters, and it may compete for food and space. Goldfish have destroyed some amphibian populations in other parts of the world by consuming frog eggs (Coad and Abdoli, 1993b). The Green Front of Iran recommended the release into pools of mosques, parks or natural lakes of the estimated 20 million goldfish kept in aquaria for the Iranian New Year celebrations in March each year. This would have a deleterious effect on habitats not yet colonised by this exotic species. A news report in 2005 cites the death of 5 million fish in transit from the store to the Iranian home at New Year, indicating perhaps that the numbers that do make it are much higher (www.politicalgateway.com, downloaded 5 August 2005). Newspaper articles suggested that goldfish should only be released into "pools" rather than rivers because of all the attendant dangers of this exotic. They are known to prevent reproduction of native species in Sistan (*Iran Daily*, 17 March 2005, p. 5). Release into the environment is illegal according to the Environmental Protection and Enhancement agency. Other problems with *Carassius* species include uprooting of submerged plants while feeding and an increase in turbidity, reducing reproductive success of amphibians, and competition with native fish species causing a reduction in their population (Halas *et al*., 2018).

Faghani Langroudi *et al*. (2015) produced useable gelatin from the skin of fish identified as *Carassius carassius* (possibly *C. auratus*) and detailed the effects of extraction time.

Goldfish are known to control mosquito larvae in Bengal (Chandra *et al*., 2008).

Robins *et al*. (1991) listed this species as important to North Americans. Importance was based on its use in textbooks, in aquaria and in aquaculture, as bait, as an experimental species and because it has been introduced outside its natural range. There are numerous, commercial aquarium forms with particular morphologies and colours that are assigned common names, e.g., black-moor, calicoe, comet, common, egg-fish, fans, telescope-veiltail, lionhead, oranda, shubunkin, veiltail. Balon (2006) reviewed the origin of the species.

**Experimental studies.** This species is widely used in Iran as an experimental organism in aquaria and as a bioindicator in the natural environment, with extensive studies starting in the 21st century. Most fish are probably *C. auratus* but some are identified as *C. carassius* and *C. gibelio*.

*Pollution:-*

A number of studies on pollutants in goldfish from the Anzali Wetland, where the species is abundant, are summarised in this paragraph. Bioaccumulation of heavy metals at Anzali was lower in muscle tissue compared to that in the liver of the predator *Esox lucius* (northern pike) (Ebrahimpour *et al*., 2011) (the species was identified as *C. gibelio*). Baramaki Yazdi *et al*. (2012) compared bioaccumulation of the heavy metals cadmium, chromium, copper, lead and zinc in *Esox lucius* (northern pike) with goldfish in the Wetland and found less in the latter except for smaller goldfish and copper. Sakizadeh *et al*. (2012) examined fish from the Wetland as bioindicators, finding levels of mercury, for example, were below criteria precluding human consumption but showed a significant deterioration in the ecosystem in recent years. Heidari *et al*. (2014) showed that goldfish were resistant to aquatic pollutants (bisphenol A, butachlor and naphthalene) and response time to environmental stress was 3-5 days. Alidoust *et al*. (2015) examined fish (identified as *C. a. gibelio*) and found the mean concentration of total mercury did not exceed the maximum level recommended by the World

Health Organization for human consumption (0.5 mg/g). The maximum allowable consumption of fish per month was three in the east of the wetland and five in the west for children or 13 and 25 for adults. Ghafari Farsani *et al*. (2015) studied the effects of cadmium on liver tissue and found necrosis, atrophy and cloudy swelling of cells, increasing with time and dose. Khanipour *et al*. (2015) found fish from the Wetland showed no differences in levels of cadmium, lead and zinc between three stations (west, centre, east) but lead and zinc levels were higher than international standards for this commercial species. Khanipour *et al*. (2017) studied the accumulation of heavy metals (chromium, cobalt, copper, nickel) in edible muscle tissue of fish from the Wetland and found that, although overall the fish were suitable for human consumption, nickel levels were near the permissible limit. Moradi *et al*. (2017) measured the amount of the hydrocarbon benzo[a]anthracene in fish identified as *Carassius carassius* (probably *C. auratus*) from the Wetland, finding no significant differences between sample areas and levels lower than international health standards (20 μg/kg dry matter). Seifzadeh *et al*. (2018) found bioaccumulation of the pesticides aldrin, diazinon and endrin in muscle tissues of fish from the Wetland were lower than international detection limits and so consumers were not at risk.

Shahsavani *et al*. (2003, 2004, 2005) and Shahsavani and Movassaghi (2003) studied the effects of anionic detergents (shampoos, a common water pollutant) on blood parameters, on hepatic and renal pathology, and on serum biochemical parameters. Shahsavani *et al*. (2003) recorded the formation of lesions and clinical changes in fish exposed to kerosene. Shahsavani *et al*. (2009) found a protective effect of dose-dependent thiamine on lead poisoning lesions of the brain, kidney and liver.

Ansari and Raissy (2011) found fish, identified as *C. a. gibelio*, from the Beheshtabad River had mean concentrations of 138.6, 174.8 and 66.4 μg/kg for copper, iron and zinc, attributable to fertilisers from agriculture, but levels were safe for human consumption. Jahanbakhshi *et al*. (2012) investigated the toxic potential of nanometer-sized particles of silver, used as coatings in various applications and found in ecosystems. Banaee *et al*. (2013) found lead to accumulate differently in various tissues, muscles the least and viscera, followed by gills, the most. Fatahi (2013) exposed male goldfish to 3 and 6 mg/l concentrations of the organophosphate insecticide diazinon and found some focal degeneration and necrosis of kidney tubules and hyperplasia and adhesion in gill lamellae but no changes in the intestine. Changes increased with toxin concentration. Rakhshi *et al*. (2013) found that sexual behaviour stopped at high concentrations (40 μg/l) of copper sulphate by disturbance of olfactory receptors. Taghizadeh *et al*. (2013) found yolk-sac larvae (as *C. a. gibelio*) could tolerate a wide range of pH, with higher survival between 5.75 and 6.7, and with low pH combined with high aluminium (a common element in the environment) being more toxic. Taghizadeh *et al*. (2013) also documented the effects of exposure of these larvae to low pH and aluminium on sodium exchange, development and mobility. Tarkhani and Hedayati (2013) investigated the acute toxicity of the pesticides diazinon and deltamethrin in mature fish identified as *C. a. gibelio*, and found 100% mortality at 40-80 mg/l diazinon and 2.04 mg/l deltamethrin. Ahmadivand (2014) found the $LC_{50}$ 96 h for the heavy metal pollutants lead chloride, mercuric chloride and zinc chloride were 88.8, 0.87 and 92.6 mg/l respectively. Forsatkar *et al*. (2014) examined the interaction of fluoxetine and diclofenac (drugs that end up in waterways) on food intake, the former decreasing and the latter increasing, intake. Forsatkar *et al*. (2015) also found fluoxetine decreased food intake and also affected feeding behaviour, in searching and consumption of food. Hedayati *et al*. (2014) investigated gill tissue lesions during sublethal

exposure to cadmium chloride, and this could be used to evaluate this heavy metal's effect on natural ecosystems experimentally. Hedayati and Ghafari (2014) studied the effects of chlorine bleach on this fish finding acute toxicity at 41.79 mg/l and greater resistance than bighead carp. Shahbazi *et al*. (2014) found the agricultural fungicide edifenphos had an $LC_{50}$ 96 h of 4.022 mg/l, indicative of a toxic pesticide. Fish exhibited a hunched spinal column and irregular swimming among other conditions when exposed to this chemical.

Abarghouei *et al*. (2015) found significant effects of silver nanoparticles on blood erythrocytes but not leucocytes. Hedayati and Jebaleh (2015) determined the $LC_{50}$ 96 h for cadmium chloride was 11.2 mg/l, considered rarely toxic, and goldfish were more resistant than common carp. Hesnentajenaaza *et al*. (2015) determined the $LC_{50}$ 96 h of the insecticide chlorpyrifos was 83.2 mg/l while diazinon and deltametrin were more toxic. Khalili (2015) found that increases in amount and exposure duration of zinc oxide nanoparticles increased damage to gills. Shahbazi Naserabad *et al*. (2015) measured the $LC_{50}$ 96 h for the pesticides honosan (4.02 mg/l) and malathion (4.71 mg/l) which showed medium toxicity and caused behavioural changes. Hedayati and Bagheri (2016) found that titanium dioxide nanoparticles, widely found in consumer products, had negative effects on blood parameters, reducing red blood cells and haemoglobin, eventually causing death ($LC_{50}$ 96 h was 19,985 p.p.m.). Hedayati *et al*. (2017) indicated that a 50% lethal concentration of nanoparticles of copper, titanium and zinc caused tissue damage and destruction and also sub-lethal toxicity of nano-zinc oxide was higher than nano-copper oxide and nano-titanium dioxide and caused much wider effects on gill tissue. Samadzadeh *et al*. (2017) reported an $LC_{50}$ of 0.36 p.p.m. for colloidal silver nanoparticles while Samadzadeh *et al*. (2018) gave 36.36 p.p.m. Zarei *et al*. (2017) found a variety of histopathological changes in kidney and muscle tissue of goldfish exposed to the herbicide butachlor, with the most damge at 0.28 ml/l. Hanayi Kashani *et al*. (2019) examined the effects of lethal and sub-lethal levels of malathion in male goldfish, finding $LC_{50}$ 96 h was 12.5 mg/l while 0.1 $LC_{50}$ exposure showed haematological, liver histology and liver enzyme effects. Solgi *et al*. (2019) found iron to have the highest metal content in fish from Manjil Dam, the lowest and highest levels of copper, iron and zinc were in muscle and gill tissues, respectively, and copper and zinc levels were lower than international standards while iron was low to high depending on the standard used.

Abarghouei *et al*. (2020) examined the effects of two sizes (0.25 and 8.0 μm) of polystyrene microplastics on the liver and intestines of goldfish. Intestinal tissue lesions showed different complications such as necrosis, loss of intestinal villi, vacuolation, villi decay and degeneration of epithelium in both size groups compared to a control group. In general, microplastics had destructive tissue effects and most tissue lesions were observed at the highest concentration (5 mg/l). The severity of particles with a size of 0.25 μm was higher than the size of 8.0 μm, with destructive effects observed first in the intestine and then in the liver. Abarghouei *et al*. (2021) also demonstrated the toxic effects of microplastics in goldfish finding histological lesions in the liver, intestine and gills. The severity of lesions showed a size and dose-dependent pattern. The polystyrene microplastic induced the antioxidant system of exposed fish through elevating the levels of SOD and CAT activity and significant difference in expression of antioxidant related genes (CAT, SOD and HSP70). Golshan *et al*. (2020) suggested bisphenol A, widely used in consumer goods and medical tools and a known endocrine disrupter negatively affecting reproduction, can be detected using an *in vitro* approach in goldfish as an alternative to an *in vivo* test to detect estrogenic effects. Imanpour and Moosavi (2020) studied the effect of chlorpyrifos agricultural insecticide on sex hormones

and gonadal quality, finding a reduction in both in males with the most impact at a 0.75 ml/l treatment. The $LC_{50}$ 96 h was 83.2 mg/l. Fadaei Rayeni *et al*. (2021) recommended the use of a dietary extract from the tea plant, *Camellia sinensis*, to increase physiological capacity and reduce liver damage in exposure to wastewater and industrial contaminants such as cadmium and mercury. Hassanpour *et al*. (2021) concluded that both aflatoxin $B_1$ and zeralenone alone reduced growth indices and changed body composition, but the simultaneous presence of the two toxins had the greatest effect on these indices.

*Diet:-*

Alishahi and Mesbah (2012) found that extracts of the herb *Viscum album* (mistletoe) had significant effects on immune and growth stimulation while *Nigella sativa* (fennel flower) did not, and neither affected survival. Hanaee Kashani *et al*. (2012) found that adding vitamin E and highly unsaturated fatty acids to the diet of juvenile goldfish (identified as *C*. *a*. *gibelio*) had significant effects on cholesterol and glucose levels but not final weight, specific growth rate, feed conversion ratio, condition factor and survival. Kashani *et al*. (2012a, 2012b) examined the significant effect of dietary vitamin C and E and highly unsaturated fatty acid on blood parameters, gonad characteristics, hatching rate and fertilisation success. Rahmati *et al*. (2013) fed goldfish larvae *Artemia* nauplii enriched with unsaturated fatty acid and vitamin C and found a better growth rate, survival rate, tolerance of high temperature, and resistance to hypoxic stress compared to controls. Rahnama *et al*. (2013) showed that including the dietary prebiotic inulin at various levels for fish identified as *C. a. gibelio* increased growth but not survival, increased crude lipid but not body protein, and increased resistance to high pH and thermal stress but not low pH and salinity stress, a level of 1.5 g/kg being advocated as best. Akrami *et al*. (2015) corroborated the functionality of dietary prebiotic inulin in positively affecting growth performance, beneficial intestinal microbiota and stress resistance in fish identified as *C*. *a*. *gibelio*. Tarkhani (2013) found that dietary 17-β estradiol, a natural estrogen, fed to fingerlings (identified as *C*. *a*. *gibelio*) at 25 and 50 mg/kg resulted in an all-female product but metabolism and growth were reduced at high doses. Tarkhani *et al*. (2015) confirmed that 17-β estradiol had negative effects on growth parameters. Mahghani *et al*. (2014) studied the effect of the dietary synbiotic biomin imbo on *C*. *a*. *gibelio* juveniles, finding those fed 2.0 g/kg synbiotic showed improved growth performance, feed efficiency and immune response but no difference in survival.

Beshkar Dana *et al*. (2015) and Moghaddasi (2015) found that biomin imbo increased growth performance in oranda goldfish at a best dosage of 2 g/kg; oranda goldfish have a bubble-like hood, growth or wen on the head. Bagheri and Hedayati (2016) studied the effects of the dietary supplements diadzein and genistein (isoflavones from soybeans) and found exposure in early life stages caused alterations in the reproductive organs and influenced sex steroidogenesis. Hosseini *et al*. (2016, 2017) examined the effect of dietary *Lactobacillus acidophilus* on skin mucus protein pattern, immune and appetite related genes expression and growth performance in goldfish (identified as *Carassius a*. *gibelio*) and found no effects on growth performance but immune and appetite related genes expression as well as skin mucus protein profile were affected. Zadmajid *et al*. (2016) found that fish (identified as *C*. *a*. *gibelio*) fed high concentrations of thyme extract (800 mg/kg) showed a positive impact on growth factors and reduced stress when exposed to nanosilver. Ahmadnia *et al*. (2017) examined the effects of lactoferrin and *Lactobacillus rhamnosus* in the feed on the physiology and histology of the gut and ovary. The use of the latter was found to be an appropriate choice for feed efficiency improvement. Ahmadniaye Motlagh *et al*. (2017) found that the use of apple cider

vinegar in the diet was beneficial because of the antibacterial properties, the presence of beneficial nutrients and the adjustment of pH of the digestive tract, all tending to increase growth. Daryayelaal *et al*. (2017a, 2017b) studied the effect of dietary rice hull extract on survival rate and nutritional and growth factors, finding 1,000 mg/kg of feed had the best result economically. Farvardin *et al*. (2017) administered the dietary prebiotic galactooligosaccharide at 1 and 2% over six weeks and found increased safety due to an increase in total protein, albumin, globulin, lysozyme, alkaline phosphatase, agglutination and complement activation but, despite various other reports of growth performance improvement, no difference in growth and decreased gene expression levels of ghrelin, which triggers appetite and growth. Seiedi and Kalbassi (2017) determined that 0.5 and 1.0 mg/kg of nano-selenium in the diet improved growth and gonad indices, and increased the activity of the antioxidant seminal plasma enzymes. Nezhad Moghadam *et al*. (2018a) found that diet supplemented with yarrow (*Achillea millefolium*) could modulate skin mucus immunity as well as expression of inflammatory cytokines. Nezhad Moghadam *et al*. (2018b) found that diet supplemented with nettle extract (*Urtica dioica*) had significant effects on progesterone levels in females at 2g/kg. Sadeghi *et al*. (2018a) studied the effect of dietary lipid levels on growth and survival and found the optimum lipid level was 15%. Adelian *et al*. (2019a) studied the effect of dietary combo multi-enzyme and found 750 mg/kg was the best for growth and 1,000 mg/kg for improving reproductive performance. Adelian *et al*. (2019b) studied the effect of dietary natuzyme multi-enzyme and found 250 mg/kg had the best weight gain, specific growth rate, feed conversion ratio, body weight gain percentage and protein efficiency while 500 mg/kg produced the highest gonadosomatic index, fecundity, fertilisation rate and larval survival rate but no level had any effect on hatchability or sperm motility. Dadgar *et al*. (2019) found fingerlings fed 0.5 mg/kg garlic powder (*Allium sativum*) has the highest survival rate, and best growth performance and feed efficiency. Heidarieh and Sheikhzadeh (2019) indicated that green tea catechin in the diet of juveniles, especially at 500 mg/kg, could exert beneficial effects on some biochemical parameters and skin mucosal immunity in fish identified as *Carassius carassius*. Catechins are natural antioxidants that help prevent cell damage. Jafari *et al*. (2019) investigated the protective effect of raffinose oligosaccharide and *Pediococcus acidilactici* bacteria on carcass composition of fish exposed to nano-silver, finding no appropriate effect. Jafari *et al*. (2019) also found there was no significant difference between moisture content, ash, protein and carcass fat although raffinose supplementation had the greatest effect on carcass fat. Jahanbakhshi *et al*. (2019) administered zinc sulphate, an essential micronutrient, in the diet of juveniles and found 150 mg/kg gave a greater specific growth rate and lower feed conversion ratio than lower amounts, and also stimulated insulin-like growth factor secretion from the liver. Kalbassi (2019) found that fry fed organic selenium at 0.5mg/kg of diet showed significantly higher body weight, antioxidant function and gonadal development. Rokhnareh *et al*. (2019) used 3% pomegranate peel extract (*Punica granatum*) in the diet to reduce intestinal gram-negative bacteria, as higher levels reduced growth. Rostamzadeh *et al*. (2019) showed that 5 g/kg of sodium acetate in the diet could increase growth but there was no notable effect on the activity of the digestive enzymes. Sahraei *et al*. (2019) found that 2% dietary prebiotic galactooligosaccharide in young *Carassius a. gibelio* had a significant effect on villus length, width and absorption surface but no effect on growth. Sedighi *et al*. (2019) showed that dietary malic acid did not affect growth performance and intestinal histomorphology of young fish. Sheikhzadeh and Mousavi (2019), under experimental conditions, found the optimal supplementary level of ethanolic green tea

extract was 50 mg/kg with potential to positively influence some biochemical parameters and antioxidant status. Tizkar *et al*. (2019) showed that a diet containing 150 mg/k of astaxanthin brought about a superior impact on the reproductive qualities of female goldfish breeders, the eggs as well as the larvae. The hatched eggs, the larvae produced in the treatment and the survivability rate were higher, creating better production efficiency.

Hosennezhad Jadidi *et al*. (2020) added *Aloe vera* powder to the diet and found increased growth performance and improved haematological indices at 10 g/kg. Lebria *et al*. (2020) recommended olive pomace (pulp oil) up to 2% as various growth factors increased although haematological indices showed not significant differences. Mousavi and Heidarieh (2020) showed that the administration of 1 and 2 g/kg of dietary commercial rosemary extract (*Rosmarinus officinalis*) had the potential to improve some antioxidant indices, as well as protecting the liver. Sadeghi *et al*. (2020) evaluated the effects of dietary livergol (silymarin, a hepatoprotective) on growth indices and gonadal development showing increased growth (at fat 15% and livergol 0.5%) and all ovarian stages were similar with various treatments apart from one. Sepehrfar *et al*. (2020) administered 0.9 x $10^7$ CFU/g (colony-forming unit or number of viable cells) of *Pediococcus acidilactici* bacteria and 10g/kg of the trisaccharide raffinose in the diet and found some improved growth factors (rate of body weight gain, weight gain and specific growth rate) and some improved reproductive features (sperm motility duration, oocyte diameter and yolk space). Sheikhzadeh and Heidarieh (2020) supplemented the diet of *Carassius carassius* (probably *C. auratus*) with the synbiotic biomin imbo and found, especially at 5 g/kg, significantly enhanced growth performance, some biochemical parameters and skin mucosal immunity.

*Aquaculture:-*

Hassan Nataj Niazi *et al*. (2013) showed that density of fish in aquaria significantly affected growth but not survival. Faizbakhsh and Gheshlaghi (2012) studied the effects of chemical, physical and weather factors, tank environment, stocking density and feeding treatments on larval production. Mohammadzadeh *et al*. (2020) designed and produced a recombinant gonadotropin-releasing hormone (GnRH - a peptide known to regulate reproduction in vertebrates) associated peptide (rGnRH/GAP) as an alternative to previous GnRHs to induce final maturation in fish, effectively testing it in mature goldfish.

*Chemical composition and food safety:-*

Mehregan Nikoo *et al*. (2013) found that crucian carp (*Carassius carassius*, but probably *C. auratus*) protein hydrolysate had the potential to be used as a natural antioxidant in food and had possible pharmaceutical applications in the future. Saffar Shargh *et al*. (2018) used acid and basic isoelectric solubilisation/precipitation methods to extract protein from fish identified as crucian carp (*Carassius carassius*, but probably *C. auratus*). More protein was extracted using the acidic treatment but the basic treatment had better functional properties.

Roosta *et al*. (2020) indicated that biochemical factors in fish mucus are measurable and can be used as a less-invasive tool and alternative to blood extraction for monitoring the endocrine response, reproductive indices and sexual stages, especially during vitellogenesis.

*Disinfection and healing:-*

Shahsavani *et al*. (2001, 2002, 2002) examined the use of the drug phenytoin sodium on skin wounds, 5 mg/l showing the best healing improvement while zinc oxide was not as effective. Shahsavani *et al*. (2007), however, demonstrated the adverse effects of phenytoin sodium on the gills, liver and kidney. Noaman *et al*. (2010) recorded an infestation of the crustacean *Argulus foliaceus* on the lionhead form of goldfish from an Iranian breeder.

Treatment with trichlorfon cleared the parasites. Tarkhani and Imanpoor (2012) evaluated the use of salt and formaldehyde, used against ectoparasites, in terms of stress response, finding a rapid stress that is however, eliminated after 24 hours in fresh water. Salt was less stressful. Hoseini and Tarkhani (2013) studied serum biochemistry of fish treated with formalin and sodium chloride used in ectoparasite removal, recommending the latter which caused less osmotic disturbance and stress. Nematollahi *et al*. (2014) isolated and characterised macrophages, important in disease resistance, from the head kidney and spleen. Sudagar (2017b) found that adding zinc oxide nanoparticles to aquarium water had antibacterial properties, increasing with nanoparticle concentration and contact time. Sadeghi *et al*. (2018) showed that the drug livergol (a herbal extract of milk thistle) had protective effects on the liver, reducing lesions. Somesarai *et al*. (2018) showed that an ethanolic persica extract, a combination of three herbs namely *Salvadora persica* (toothbrush tree), *Achillea millefolium* (yarrow) and *Mentha spicata* (spearmint), reduced the total bacterial count on gills. Rahanandeh and Rahanandeh (2020) showed that calcium oxide at 15 mg/l had the best control effect on *Ichthyophthirius multifilis* in fish farms and sodium chloride at 2,500 mg/l had a similar effect.

*Hormones and immunology:-*

Imanpour and Kamale (2006) used human chorionic gonadotropin (NCG) to induce spawning in adults (listed as *C. a. gibelio*), the best rate being 1,500 IU/kg, and feeding larval goldfish with phytoplankton (mainly *Chlorella*), zooplankton (*Paramecium*, rotifers and *Daphnia*) and *Culex* larvae gave favourable growth and condition factors. Vaziry (2016) studied adult fish identified as *C*. *a*. *gibelio* for the effect of human chorionic gonadotropin on the immune response, biochemical parameters and serum enzymes, finding that even a single dose strongly stimulated the immune system and changed the physiological condition within a short time. Taati *et al*. (2010) studied the effects of ascorbic acid on hatching performance temperature tolerance in fish identified as *C. gibelio*. Parsiani *et al*. (2010) studied the combination effects of gonadorelin and prostaglandine hormones on semi-artificial breeding. Tarkhani *et al*. (2012) found improved fecundity and gamete quality in fish fed diets with 17•-estradiol, enabling better management of egg production for the Now Ruz culturists.

Ahmadifar *et al*. (2017) evaluated the effects of different methods of LHRHa implants and injections combined with temperature and photoperiod on properties of semen (spermatocrit percent, spermatisation volume) and female factors (ovulation, hatch percent, gonadosomatic index) and changes in steroid hormones in both sexes. Hoseinzadeh Sahafi *et al*. (2018) showed that chasteberry (*Vitex agnus-castus*) extract had inhibitory effects on growth and development of the oocyte and the reproductive performance of goldfish. Sepehrfar *et al*. (2019) administered 0.9 x $10^7$ CFU/g (colony-forming unit or number of viable cells) of *Pediococcus acidilactici* bacteria and 10g/kg of the trisaccharide raffinose in the diet and found improved mucosal immune parameters and intestinal histomorphology.

Falahatkar *et al*. (2020) determined that biochemical factors in mucus were measurable and this was a less invasive tool than blood extraction for monitoring endocrine response, reproductive indices and sexual stages, especially vitellogenesis. Mohammadian *et al*. (2020) used recombinant gonadotropin releasing hormone to induce final maturation and found it had a good biological activity and can be introduced as a suitable alternative for the treatment of reproductive disorders in goldfish. Rashmeei *et al*. (2020) studied the stimulatory effect of dietary chasteberry (*Vitex agnus-castus*) extract on immunity, some immune-related gene expression, and resistance against *Aeromonas hydrophila* infection and found 15 g/kg had an

immunomodulatory effect by stimulating the innate immunity and some inflammatory cytokines as well as disease resistance against the bacterium. Rashmeei *et al*. (2021) assessed dietary chaste tree or chasteberry (*Vitex agnus-castus*) fruit extract on growth performance, haemato-biochemical parameters, and mRNA levels of growth and appetite-related genes and found positive effects on growth-related traits and haematological parameters at 1.5%. Valipour and Heidari (2021b) examined reproductive performance (fecundity, fertilisation and hatching) of *Carassius auratus* after injection of different kisspeptin neuropeptides and found a significant increase compared to ovaprim. The highest level of these indices was recorded in a human kisspeptin treatment.

*Spermatology:-*

Bahmani *et al*. (2007) found cortisol caused testicular apoptosis in immature, but not mature, fish. Zadmajid *et al*. (2008) showed hormonal GnRHa and pituitary extract proved more effective on spermatological parameters than the hormone hCG. Zadmajid and Imanpour (2009) studied the effects of seminal plasma indices on sperm motility and Zadmajid *et al*. (2009) the effects of hormones on seminal plasma biochemistry.

Taati *et al*. (2010a) examined coelomic fluid composition and its effects on sperm motility and Taati *et al*. (2010b) the correlation between chemical composition of seminal plasma and sperm motility (both in fish identified as *C. gibelio*). Taghizadeh *et al*. (2013) investigated the effect of sperm extenders and different concentrations of the cryoprotectant dimethyl sulphoxide on sperm survival and motility in goldfish (as *C. a. gibelio*) and Taghizadeh *et al*. (2013) similarly studied extenders and different concentrations of methanol. Successful sperm storage methods tend to vary with the species and needed to be determined in fish used in research.

Esmaeilbeigi and Kalbassi (2015a, 2015b) used single-cell gel electrophoresis (or comet assay) to study DNA damage in liver cells and to optimise sperm cells. KhakaShour and Kalbassi (2015a, 2015b) examined the effects of different levels of the essential trace element selenium in the diet on sperm quality and sperm DNA quality, finding 0.5 mg/kg had the highest efficiency on sperm quality and the lowest DNA damage. Niazi *et al*. (2016) showed that increasing stocking density decreased spermatocrit, sperm density and duration of sperm motility. Sadeghi and Imanpoor (2016) examined the effects of different extenders and cryoprotectant concentrations on the quality of post-thawed sperm after freezing for five and 10 days. Nezafatian and Zadmajid (2018) studied the effect of genistein on seminal plasma biochemical parameters and enzymes in spermiating male gibel carp (*C. a. gibelio*), finding that the amount of genestein (a phytoestrogenic compound) in broodstock aquafeeds should be monitored, since high doses impaired sperm quality by changing the seminal plasma composition. Sabri Asi *et al*. (2018) showed that hormonal ovaprim and HCG (human chorionic gonadotropin) were more effective on spermatological parameters than pituitary extract in fish identified as *C. a. gibelio*.

*Haematology:-*

Hanaee Kashani *et al*. (2017) found that adult male fish were affected by high concentrations of diazinon and had the lowest alkaline phosphatase but alanine transferase, aspartate amino transferase, glucose and total protein increased significantly. Hedayati and Jahanbakhshi (2017) showed sub-lethal concentrations of nano-zinc oxide affected haematological parameters of goldfish which have more resistance to this kind of pollutant. Jahanbakhshi *et al*. (2017) found that zinc sulphate in the diet stimulated the immune system and had positive effects on health and haematological factors. Jafari *et al*. (2018) showed that a

dietary supplement of *Pediococcus acidilactici* bacteria and raffinose oligosaccharide had positive effects on haematological parameters of fish exposed to silver nanoparticles. Nejad Moghaddam *et al*. (2018) found that adding nettle (*Urtica dioica*) extract at 4g/kg to the diet improved albumin levels but had no effect on haematological parameters nor on glucose, cholesterol or triglyceride levels. Abarghouei *et al*. (2020) showed that different concentrations of silver nitrate, used in industry for its antibacterial properties, reduced blood erythrocytes but did not affect blood leukocytes under experimental conditions.

*Stress:-*

Golestani Bahkt (2011) found that goldfish learned helplessness after shock exposure, as do other organisms. Imanpoor *et al*. (2011) examined the effect of light and music on growth performance and survival rate, finding music had no effect whereas light significantly affected food conversion rate and specific growth rate, with white light showing better growth than red. The authors concluded that the fish could distinguish music from other environmental stressful sounds. Akhavan *et al*. (2013) exposed fish to acute stress (chasing and air exposure) and found some blood parameters were significantly higher while others were not and concluded this species is not adapted to acute stress. Zolfaghari and Imanpour (2013) found that red light caused stress in goldfish reflected in decreased growth but music did not induce stress. Eslamloo *et al*. (2014) showed that recurrent acute stress (chasing and air exposure) could immunosuppress goldfish.

Eslamloo *et al*. (2015) showed that red and blue coloured tank backgrounds were chronically stressful and immuno-suppressive, a white background was best for growth but resulted in loss of skin colour. Khandan Barani and Heydari (2018) found a higher stocking density caused chronic stress and altered such parameters as cortisol, glucose, alkaline phosphatase and red blood cells, all of which were higher than fish kept at a lower density.

*Anaesthesia:-*

Sedigh Eteghad *et al*. (2008) compared the anaesthetising effects of the medical herbs *Valerian officinalis* (valerian), *Melissa officinalis* (lemon balm), *Papaver somniferum* and *P. bracteatum* (opium and Iranian poppies), finding that lemon balm had a lower time to anaesthesia and recovery than valerian (the poppies gave biased results and were not considered). Hoseini and Ghelichpour (2013b) found that fish anaesthetised with eugenol (a plant essential oil extract) should be with high concentrations over a short period to reduce stress. Rahmati-holasoo *et al*. (2014) showed that clove oil could be used repeatedly for at least 2 weeks as an anaesthetic in this species and Khosravanizadeh (2018) showed that 75 p.p.m. was the lowest effective concentration lasting for 115.2 seconds with a recovery time of 191.2 seconds.

**Conservation.** This species is a successful exotic, in no need of conservation. Listed as of Least Concern by the IUCN (2015) for its native range.

**Sources.** Iranian material:- CMNFI 1979-0110, 2, not kept, Fars, lake in Park-e Shahr, Shiraz (29º38'N, 52º32'E); CMNFI 1979-0230, 41, 14.7-38.6 mm standard length, Sistan, Hamun-e Puzak (ca. 31º15'N, ca. 61º42'E); CMNFI 1991-0162, 1, 40.5 mm standard length, Mazandaran, Bagher Tangeh (36º42'N, 52º43'E); CMNFI 1993-0136, 1, 64.0 mm standard length, Mazandaran, Sardab River (36º39'42"N, 51º22'36"E); CMNFI 2008-0110, 1, 91.3 mm standard length, Gilan, swamp near Hendeh Khaleh (37°23'N, 49°28'E); CMNFI 2008-0111, 4, 16.4-51.0 mm standard length, Gilan, Caspian coast near Hendeh Khaleh (37º23'N, 49º28'E); CMNFI 2008-0113, 1, 57.7 mm standard length, Gilan, near Khoshk Bijar (ca. 37º22'N, ca. 49º47'E); CMNFI 2008-0158, 1, 49.2 mm standard length, Lake Urmia basin (no other locality

data); CMNFI 2008-0163, not kept, Khuzestan, Marun River at Chahar Asiab (30º40'28"N, 50º09'34"E); CMNFI 2008-0168, not kept, Khuzestan, Dez River at Harmaleh (31º57'08"N, 48º33'48"E); CMNFI 2008-0178, not kept, Khuzestan, Karun River at Ahvaz (31º19'N, 48º42'E); CMNFI 2008-0204, 1, 92.8 mm standard length, Sistan (no other locality data); CMNFI 2008-0237, 2, 94.9-102.9 mm standard length, Kermanshah, Yavari Spring (34º28'N, 46º56'E).

## Genus *Cyprinion*
Heckel, 1843

This genus contains about eight species in Southwest Asia with 5-6 in Iran. It is characterised by a moderate-sized, compressed body, a thick and blunt snout, an inferior mouth with a straight, crescentic or arched shape and a sharp horny edge to the lower jaw (which may fall off in preserved specimens), one pair of small barbels at the mouth corner, the last dorsal fin unbranched ray is thickened and bears weak to strong serrations (highly variable between individuals within a species and not a good character in species definitions), the dorsal fin is long (up to 17 branched rays) and the anal fin short (typically 7 branched rays), a ridge in front of the dorsal fin is formed internally from fused pterygiophores and lacks scales externally, pharyngeal teeth are in three rows and are compressed and spoon-shaped, scales large to moderate in size (lateral line counts (31-45), breast and belly scales may be absent (individually variable and not a good character), scale radii are restricted to the posterior field, the peritoneum is black, and the gut is very long and coiled (several times body length). Nasri *et al*. (2013) gave details of osteology of *C. kais* and *C. macrostomus* from Iran. Nasri *et al*. (2016a) discriminated five Iranian species using the shape of the neurocranium.

*Scaphiodon* Heckel, 1843 has been used for *Cyprinion* and *Capoeta* species in Southwest Asia and is a synonym of the latter. *Cyprinium* Agassiz, 1846 is an unjustified emendation (*Catalog of Fishes*, downloaded 2 October 2020).

Taki (1975) related members of this genus to a common ancestor with *Onychostoma* Günther, 1896, a Chinese and Southeast Asian genus although Li *et al*. (2008) found this lineage to be unsupported on DNA evidence. Howes (1982) synonymised *Semiplotus* Bleeker, 1860, a genus found from Nepal to Viet Nam, and *Scaphiodonichthys* Vinciguerra, 1890, a genus from Indochina, with *Cyprinion* and refuted Taki's (1975) view using osteological characters, particularly of the jaws. Howes (1982) considered that *Cyprinion* cannot be defined on any uniquely derived characters. Krupp (1983) considered Howes' revision as unsatisfactory for the reasons that type specimens were not examined, relationships were based on jaw anatomy and other characters were largely excluded, variability of osteological characters within a species were largely unknown, and synapomorphies were not unequivocal. Bănărescu (1992b) and Banarescu and Herzig-Straschil (1995) regarded *Semiplotus* as a distinct genus but probably related to *Cyprinion*. They commented that *Semiplotus* differs sharply from *Cyprinion s.s.* in the absence of barbels, a higher number of dorsal fin branched rays (20 or more), and in a lower number of anal fin branched rays (5 as in most related genera rather than the usual 7 in *Cyprinion*). *Scaphiodonichthys* has two pairs of barbels (only one in *Cyprinion*), and 5 anal fin branched rays as well as differing from both *Cyprinion* and *Semiplotus* by having the lateral line closer to the ventral margin of the caudal peduncle and divergent rather than parallel striae on the scales. These latter two characters justify generic separation of *Scaphiodonichthys*. Bănărescu (1997) considered *Scaphiodonichthys* as valid and not a synonym of *Cyprinion*. Characters used by others to define *Cyprinion* such as expansion

of the proximal part of the pelvic fin rays, interpelvic papillate flaps (Banister and Clarke, 1977) and a naked predorsal ridge (Mirza, 1969) do not occur in all species in this genus. If *Semiplotus* is included in *Cyprinion* then several osteological structures, particularly a synarthritic dentary joint, are uniquely derived or synapomorphic.

In the absence of a detailed revision, I have retained species within *Cyprinion* as the most familiar name in use in Southwest Asia for these fishes and the *Catalog of Fishes* agrees. *Cyprinion s.s.* is found from the Indus River basin west to the Arabian Peninsula and the Tigris-Euphrates basin but excluding northern drainages such as the Lake Urmia, Caspian Sea and Hari River basins and excluding the westernmost edge of Southwest Asia such as the Jordan River basin and coastal drainages of Israel.

The genus *Cyprinion* is currently under revision by Florian Wicker at the Senckenberg Museum, Frankfurt and the status of the following species may undergo some changes. It is interesting to note that this genus has had no new species recently described relevant to Iran, the last one being in 1880, while other genera with five or more species have been found to be more diverse recently, e.g., *Capoeta* with 10 species described in 1897 or earlier and eight after 2016 with one in 1982, and *Garra* with seven new species since 2015 and seven species from 1949 or earlier. *Luciobarbus*, however, is another genus (eight species) with no new ones described since 1914.

Saadati (1977:45) referred to a new and undescribed *Cyprinion* species from Lar in southern Iran but the fish are *C. watsoni*, a widespread and variable species (CMNFI 2007-0060). The anal fin branched ray count (6), two pairs of barbels and low lateral line scale count (26-27) are confusion with *Carasobarbus luteus* also collected at this site.

Nasri (2015) proposed that the common ancestor of Iranian *Cyprinion* species originated from eastern basins in Baluchestan (in its widest sense). Their descendents were dispersed southward and westward through palaeo-drainage connections and speciation occurred through geological and climatological phenomena such as volcanoes (*sic*) and drought.

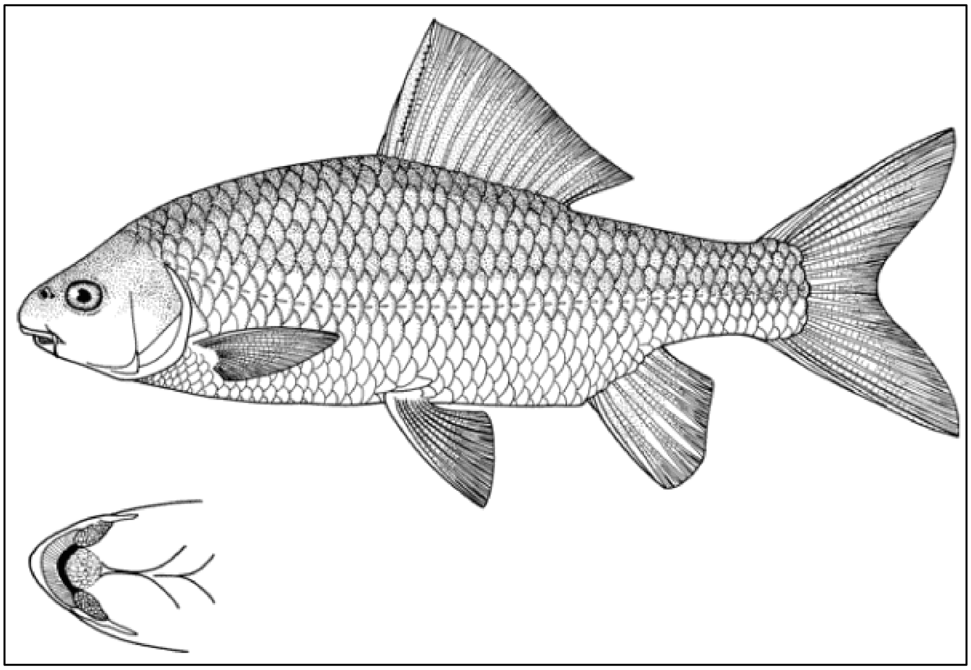
Nasri *et al*. (2019) compared Iranian species of *Cyprinion* morphometrically using 15 landmark points on 848 specimens in 22 populations. Three groups were found:- group X: *C. kais*, *C. macrostomus* and *C. tenuiradius*; group Y: *C. microphthalmum* and *C. watsoni*; and group Z: *C. milesi*. Group X was distinguished by a deeper body, least head length and depth, longest dorsal fin base and least caudal peduncle depth, *C. microphthalmum* in group Y by least caudal peduncle length and depth and *C. watsoni* in group Y by longest caudal peduncle and least dorsal fin base, and group Z by the longest anal fin base, least body depth, deepest caudal peduncle and longest head. Southeastern populations (groups Y and Z) showed more variation than southwestern and western populations (group X), attributed to unstable climatic conditions in the southeast. Lentic populations of *C. watsoni* had an elevated body shape while lotic populations were fusiform with a longer head. The authors concluded the most possible factor influencing morphological variation was habitat related differences acting on phenotypic plasticity.

The following table summarises some key distinguishing characters of the Iranian species of *Cyprinion*, although distribution is often important and some characters not shown are subtle, not easily summarised and possibly overlapping.

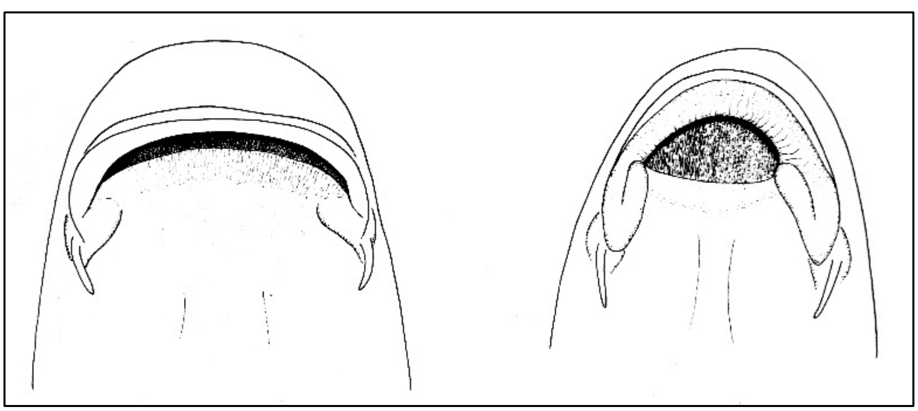
| Species/ Characters | Dorsal fin branched rays | Lower jaw | Lateral line scales | Gill rakers | Distribution |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| *C. kais* | 12-16 | Tooth-like | 36-43 | 9-15 | Persis, Tigris |
| *C. macrostomus* | 12-17 (mostly 13 or more) | Arch | 33-45 | 13-21 | Tigris |
| *C. milesi* | 9-13 (mostly 10 or less) | Oblique | 34-39 | 11-16 | Hormuz, Jaz Murian, Makran |
| *C. tenuiradius* | 11-15 (mostly 12 or more) | Arch | 32-39 | 10-21 | Lake Maharlu, Persis |
| *C. watsoni* | 9-12 (mostly 11 or less) | Arch | 31-43 | 8-18 | Bejestan, Lut, Jaz Murian, Mashkid, Hormuz, Kerman-Na'in, Makran, Sirjan, Sistan |

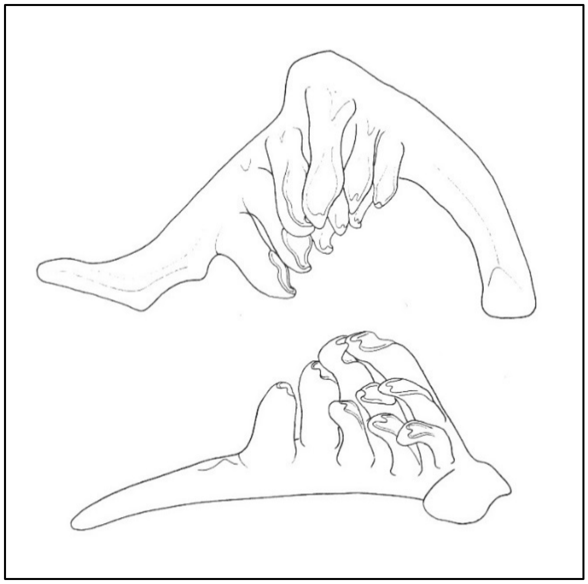
## ***Cyprinion kais***
Heckel, 1843



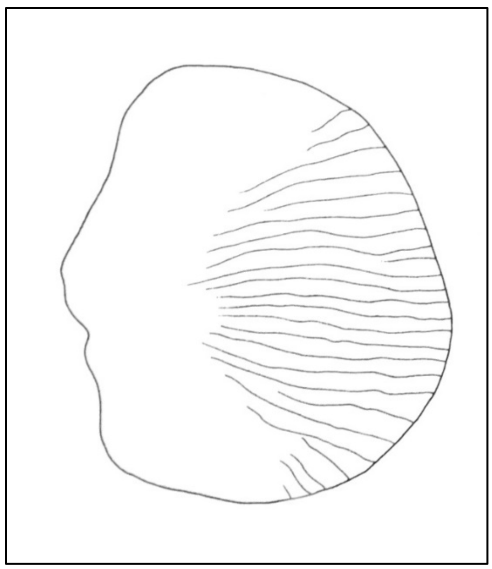
*Cyprinion kais*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Cyprinion macrostomus* (left) and *C. kais* (right) mouths, Freidhelm Krupp.



*Cyprinion kais*, pharyngeal teeth, Freidhelm Krupp.



*Cyprinion kais*, scale, Freidhelm Krupp.

*Cyprinion kais*, Khuzestan, Dez River at Dez Wildlife Refuge, 24 April 2008, Atabak Mahjoorazad.

*Cyprinion kais*, Khuzestan, Dez River at Dez Wildlife Refuge, 24 April 2008, Atabak Mahjoorazad.

*Cyprinion kais*, Syria, Freidhelm Krupp.

*Cyprinion kais*, Syria, Freidhelm Krupp.

**Common names**. Butak dahan kuchek and butak-e dehan kuchek (= smallmouth butak, meaning of butak unknown), botak, butok, lotak, lotak-e dahan koochak or kochal (= smallmouth lotak); zanboor or zanbour (= bee or wasp), zanbour dahan kuchek (= smallmouth

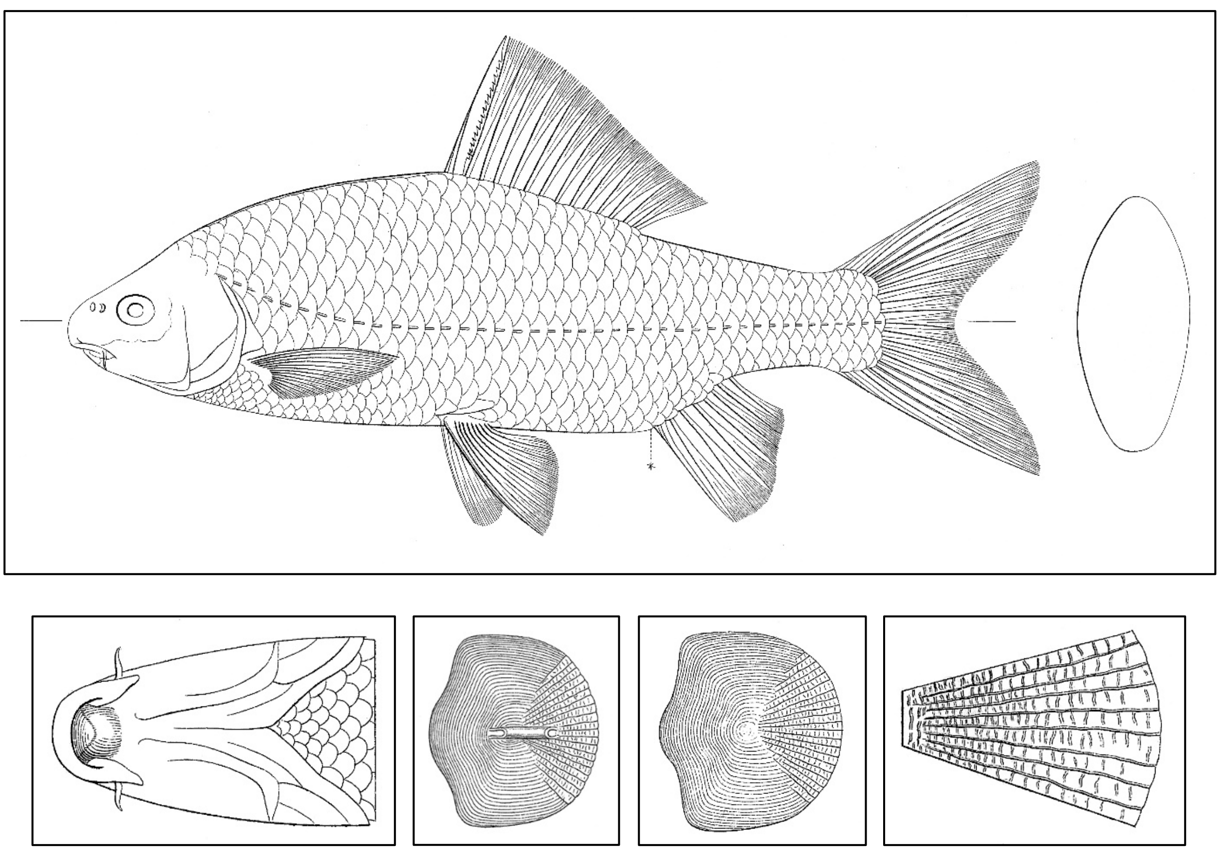
bee or wasp).

[Bnaini (or bunnayni, diminutive of bunni), bunni saghir (saghir meaning small, little); kais at Aleppo (= Haleb, Syria) (from kayis, little), hence the scientific name (all from Mikaili and Shayegh (2011), all in Arabic; kais kingfish, smallmouth kingfish, smallmouth lotak].

**Systematics.** *Cyprinion Cypris* Heckel, 1843 is a synonym, being a juvenile with keratinization of the lower jaw incomplete according to Howes (1982), although he did not examine the types. Krupp (1985c) and Banarescu and Herzig-Straschil (1995) agree with this synonymy. Berg (1949) placed *C. kais* (and *C. cypris*) in *C. macrostomus*, as the position of the dorsal fin in relation to the pelvic fins was variable in these fishes and not sufficient to warrant species status as Heckel (1843) stated in describing these species. However, *C. kais* has a unique mouth structure generally now accepted as warranting species distinction.

The type locality for *Cyprinion Kais* is “Aleppo” and “Mossul” and for *Cyprinion Cypris* the “Tigris bei Mossul” (Heckel, 1843b).

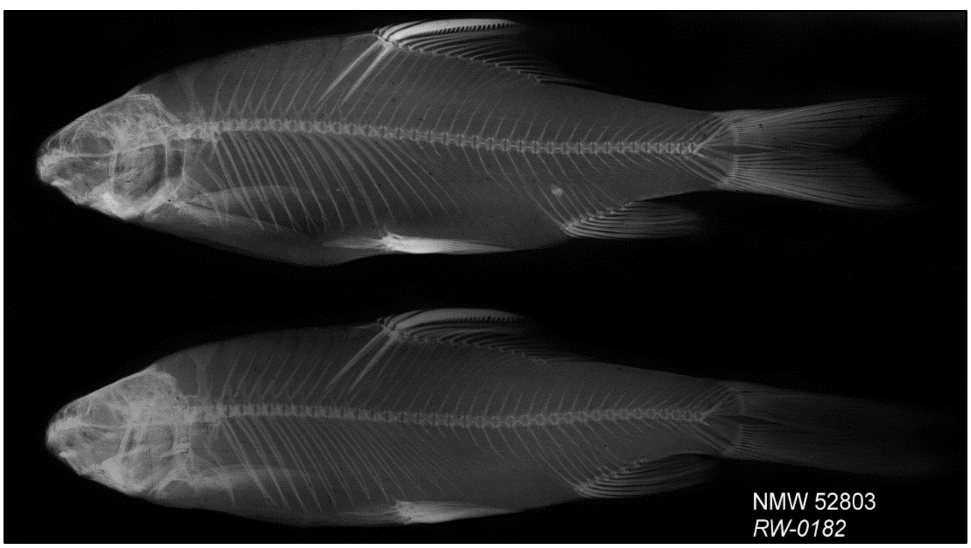
The syntypes of *C. kais* are in the Naturhistorisches Museum Wien comprising three fish in NMW 52801 (now paralectotypes) and measuring 68.5-97.3 mm standard length, two fish in NMW 52802 measuring 120.6-164.3 mm standard length, and two fish in NMW 52803 (paralectotypes) measuring 153.4-154.2 mm standard length, the smaller of these being designated as the lectotype by F. Krupp in 1984. Eschmeyer *et al*. (1996) listed possible syntypes in the Rijksmuseum van Natuurlijke Historie, Leiden under RMNH 2485 (2 fish, formerly NMW) and RMNH 2489 (1), and one syntype in the Senckenberg Museum Frankfurt (SMF 134, formerly NMW).



*Cyprinion kais*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line

(regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

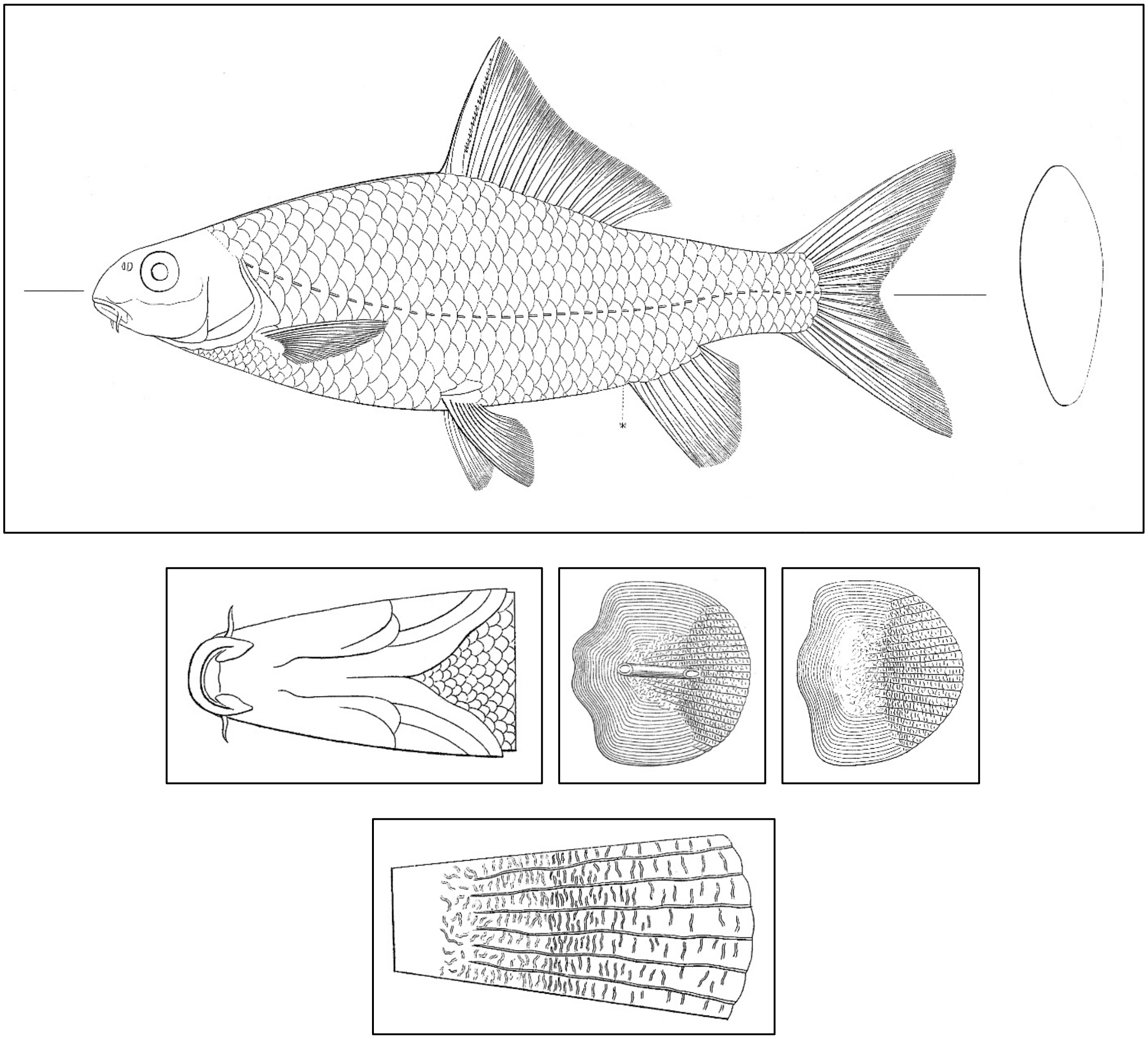

*Cyprinion kais*, lectotype and paralectotype, NMW 52803,
Naturhistorisches Museum, Wien.




*Cyprinion kais*, lectotype and paralectotype, NMW 52803,
Naturhistorisches Museum, Wien.

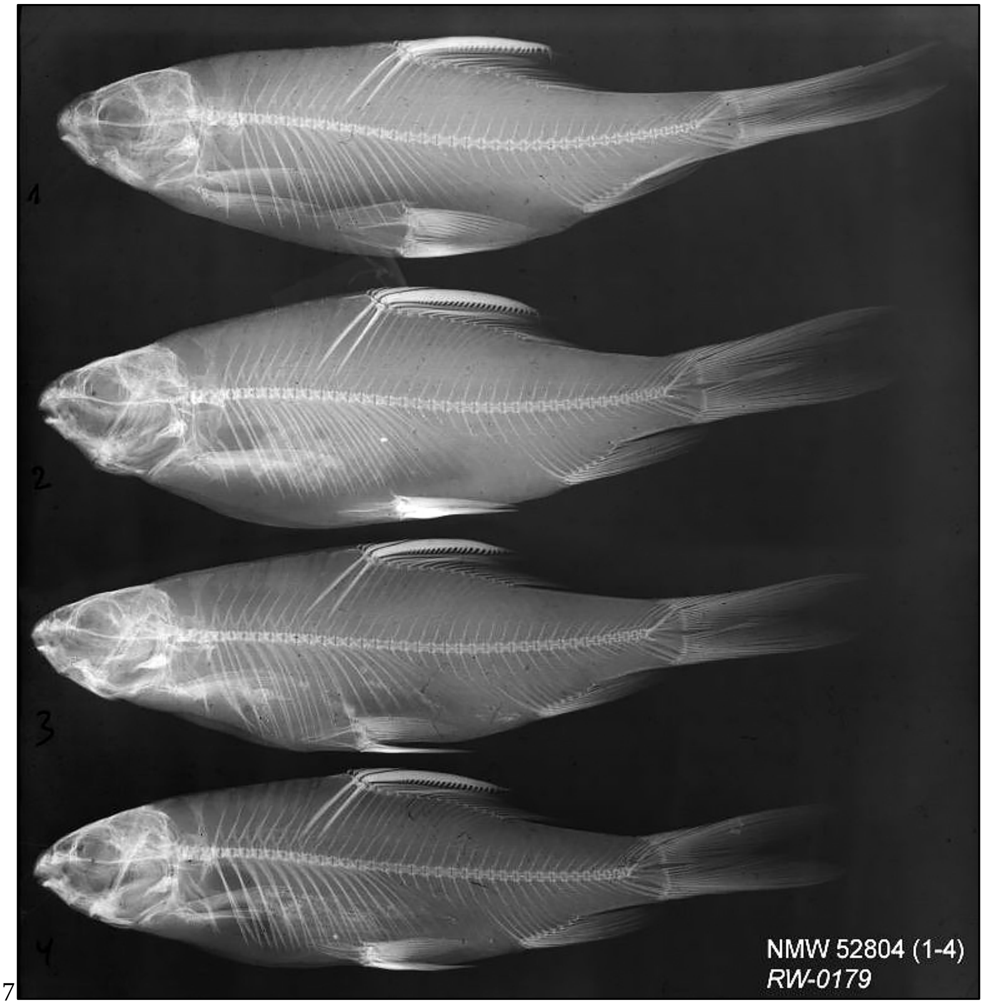

*Cyprinion kais*, NMW 52802 and
*Cyprinion macrostomus*, NMW 52805,
Brian W. Coad.

Two syntypes of *C. cypris*, 63.5-106.2 mm standard length are under SMF 849, the larger one designated as a paralectotype (March 2007). Ten syntypes are in the Naturhistorisches Museum Wien (NMW 52804) measuring 51.2-115.1 mm standard length, the largest, presumably NMW 52804.1, being designated as the lectotype (however, Banarescu and Herzig-Straschil (1995) gave 44.1-110.0 mm standard length for these 10 fish with one at 99.8 mm standard length as lectotype as selected by F. Krupp in 1984). Another specimen, 110.5 mm standard length, may also be a syntype (NMW 52800); and also NMW 59508, a dried specimen (Eschmeyer *et al*., 1996). The catalogue in Vienna listed six fish in alcohol and one fish stuffed.



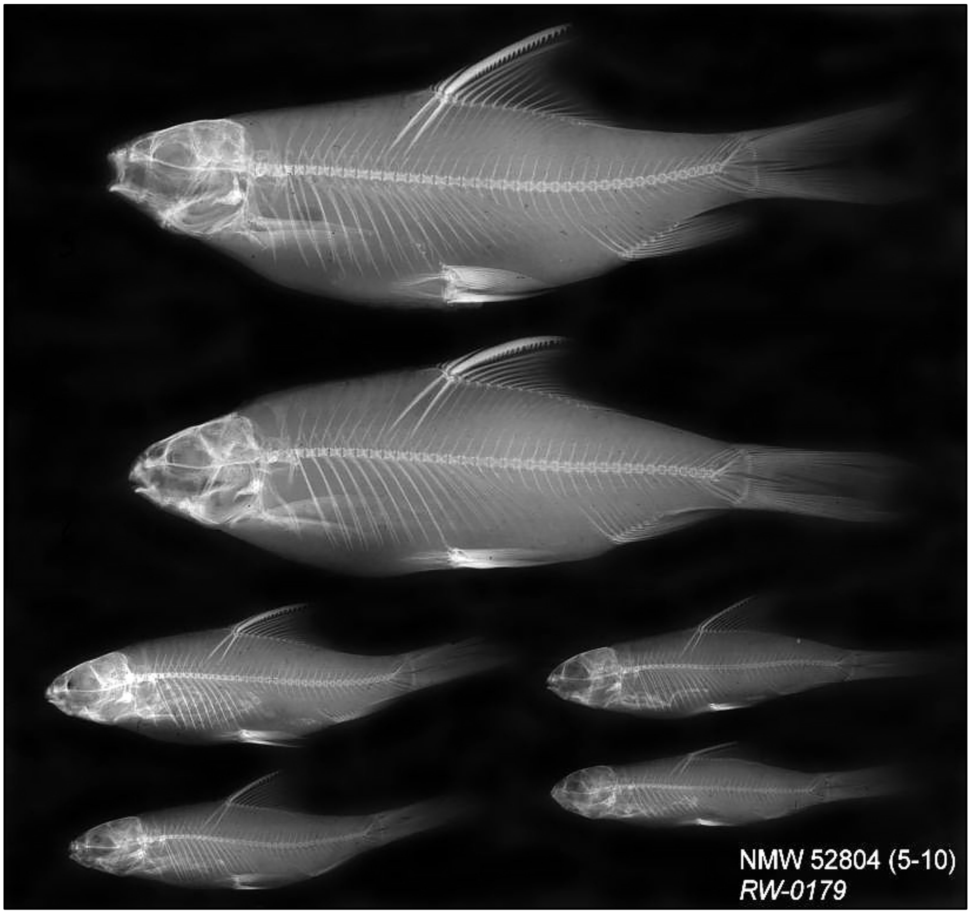
*Cyprinion cypris,*
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Cyprinion cypris*, lectotype (1) and paralectotypes, NMW 52804, Naturhistorisches Museum Wien.



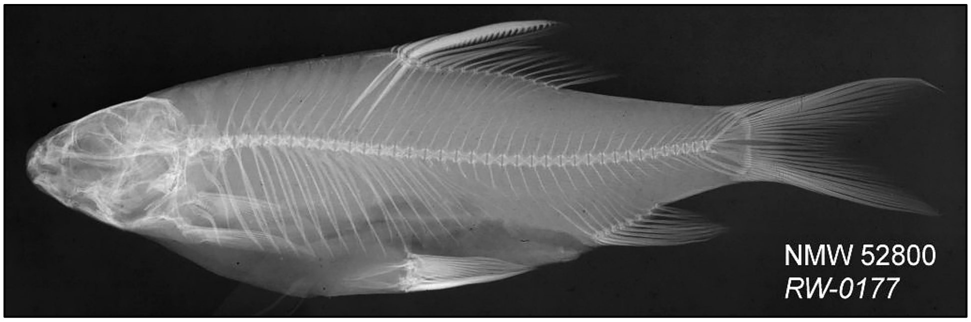

12.7
*Cyprinion cypris*, lectotype and paralectotypes, NMW 52804, Naturhistorisches Museum Wien.


*Cyprinion cypris*, paralectotypes, NMW 52804, Naturhistorisches Museum Wien.




*Cyprinion cypris*, paralectotypes, NMW 52804, Naturhistorisches Museum Wien.


*Cyprinion cypris*, probable syntype, NMW 52800, Naturhistorisches Museum Wien.




*Cyprinion cypris*, probable syntype, NMW 52800, Naturhistorisches Museum Wien.


*Cyprinion cypris*, syntype, NMW 59508, Naturhistorisches Museum Wien.

Nasri *et al*. (2010, 2013) noted that the difference level between *kais* and *macrostomus* in Durand *et al*. (2002) was the lowest among fish studied using cytochrome *b*, probably due to recent speciation. However, mouth structure is distinctive and the species is now generally accepted as distinct (*Catalog of Fishes*, downloaded 14 July 2018). Bilici *et al*. (2016) examined meristic and morphometric differences among populations in the Tigris River basin in southeast Turkey and was able to classify 96.1% of fish into three groups from the three different localities. However, sample sizes for localities were small (9, 15 and 27 specimens).

**Key characters.** Mouth shape is unique and is described below.

**Morphology.** The body is compressed and moderately deep, being deepest at the dorsal

fin origin. The predorsal profile is straight to slightly convex and there is a predorsal ridge. The caudal peduncle is compressed and moderately deep to shallow. The snout is rounded and a groove in front of the nostrils may be present or absent. The rear of the eye is positioned at the beginning of the front half of the head.

The mouth is small and semicircular with a width about the size of the eye diameter and has large lateral lobes (= lower lips) (Kafuku, 1969). The cartilaginous sheath is thickened between the corners of the mouth and is rounded posteriorly with a distinct margin. The cartilage can form a tooth-like structure protruding anteriorly from the lower lip. The mouth in *C. macrostomus* is wider, arched and lacks the lateral lobes (see also illustrations in Kafuku (1969), Krupp (1985c) and Banarescu and Herzig-Straschil (1995)). These latter authors have the width of the mouth opening as 13.5-22.0% of the head length (22.0-27.0% in *C. macrostomus*) for adult fish and the height of the arch or mouth opening (a line perpendicular from a line between the mouth corners to the tip of the lower jaw) 48-80% of the mouth width (29-47% in *C. macrostomus*), i.e., the mouth is narrower and more arched in *C. kais*. On this character, therefore, the two species can be distinguished as adults but there is potential for confusion in young fish. A single specimen identified as *C. kais* on the basis of mouth shape from the Dalaki River of Iran had values of 23.2% and 47.4% which are arguably *C. macrostomus* values. This specimen has a protruding tooth-like edge to the lower jaw in a u-shaped mouth with well-developed lips posterior to the “tooth”. Lips are moderate in width, the lower lip evident in the corners. Barbels are thin and fall short of the eye.

The dorsal fin spine is weak to moderate with moderate to strong teeth except at the extreme tip which is thin and flexible. The dorsal fin origin arises over or somewhat anterior to that of the pelvic fins. The dorsal fin margin is usually concave, sometimes deeply emarginate. The depressed dorsal fin reaches back to a level over the anal fin. The caudal fin is deeply forked with finely rounded to pointed lobes. The pelvic fin is slightly rounded and does not extend back to the anal fin origin. The pectoral fin has a straight margin and does not extend back to the pelvic fin origin.

The intestine is shorter and less complexly coiled in this species and the mean number of gill rakers is less in contrast to *C. macrostomus* (Kafuku, 1969). The back is higher and more curved, the eyes are larger and the anal fin is more posterior, in addition to the mouth shape (Heckel, 1843b). The edge of the dorsal fin is more notched in *C. kais* than in *C. macrostomus* (the length of the fourth branched ray is 48-62% of the length of the first ray as opposed to 55-79% in *C. macrostomus*, with extreme values overlapping, according to Banarescu and Herzig-Straschil (1995)). Nasri (2008) and Nasri *et al*. (2013) distinguished this species from *C. macrostomus* on osteological grounds such as deeper posterior position of the lower jaw with a much narrower labial surface, a longer last dorsal fin unbranched ray with weaker teeth and a softer and more flexible tip, and a more embowed (arched) dentary, maxillary and premaxillary. Bilici *et al*. (2017) examined fish from the Turkish Tigris River and distinguished *kais* from *macrostomus* by the former having a deeper body and the latter had a deeper head, a more anterior dorsal fin and a wider caudal peduncle. Nasri *et al*. (2018) found this species to differ from *C. macrostomus* and *C. tenuiradius* by having the lowest head depth, the largest body depth at the dorsal fin origin, the highest dorsal fin base length/standard length, the largest pectoral fin length/standard length and the largest dorsal fin height/standard length ratios.

The form of the pharyngeal teeth is different from *C. macrostomus* (see figures here after Krupp (1985c) where *kais* has hooked tips and *macrostomus* does not), there are fewer

gill rakers (8-12 on the lower arch in *kais*, 12-16 in *macrostomus*), on average there are fewer dorsal fin rays, the last dorsal fin unbranched ray is longer, and interorbital width is smaller. However, sample sizes in some studies are small (in Kafuku (1969) only five fish of each species were examined), morphometric characters are notoriously size-dependent, gill raker counts are also size dependent, and even pharyngeal tooth form varies with age (small *macrostomus* have hooked tips).

Dorsal fin with 4 unbranched and 12-16 branched rays, anal fin with 3 unbranched and 7 branched rays. Pectoral fin with 12-18 branched rays, and pelvic fin with 7-9 branched rays. Lateral line with 36-43 scales. The belly is scaled. There is a well-developed pelvic axillary scale. Scales are squarish with a rounded posterior margin, gently rounded dorsal and ventral margins and a protruding central area on the anterior margin flanked by indentations. Scales have a subcentral anterior focus, fine circuli, few to moderate numbers of posterior radii and no or very few anterior radii. Bılıcı *et al*. (2016) detailed size and shape differences in scales by sex, age and season for 82 fish from the Tigris River in Turkey. Total gill rakers number 9-15, are short, and reach the raker below when appressed. Rakers are absent on the anterior arch where there are only tubercles. Pharyngeal teeth are 2,3,4-4,3,2, with variants 2,3,5-5,3,2 and 2,3,5-4,3,2, spoon-shaped with a small hook at the tip. Total vertebrae number 37-40 (Nasri *et al*., 2018; Jouladeh-Roudbar *et al*., 2020). The lectotype and paralectotype of *C. kais*, NMW 52803, both have 39 total vertebrae. The lectotype of *C. cypris*, NMW 52804, has 40 total vertebrae and six of the paralectotypes have 39(2), 40(3) or 41(1). The probable syntype of C. *cypris*, NMW 52800, has 40 total vertebrae. Chromosome number is 2n = 50 in fish from the Godarkhosh River, Ilam (Nasri *et al*., 2010).

Meristic values for Iranian specimens are:- dorsal fin branched rays 12(2), 13(2), 14(1) or 15(1), anal fin branched rays 7 (6), pectoral fin branched rays 14(1), 15(2), 16(2) or 17(1), pelvic fin branched rays 8(4) or 9(2), lateral line scales 38(5) or 39(1), and total gill rakers 12(2), 13(3) or 14(1).

**Sexual dimorphism.** Tuberculation in a 103.5 mm standard length specimen from the Diyala River, Iraq (FMNH 51229) consisted of ca. 20 tubercles restricted to the area over the lachrymal bone. A specimen 147.5 mm standard length from Mosul, Iraq (BM(NH) 1974.2.22:115-120) had small to minute tubercles in front of the eye, under the eye, on the mid-preoperculum and on the mid-operculum. Curiously the individual small tubercles on the operculum were connected by thin lines of horny tissue.

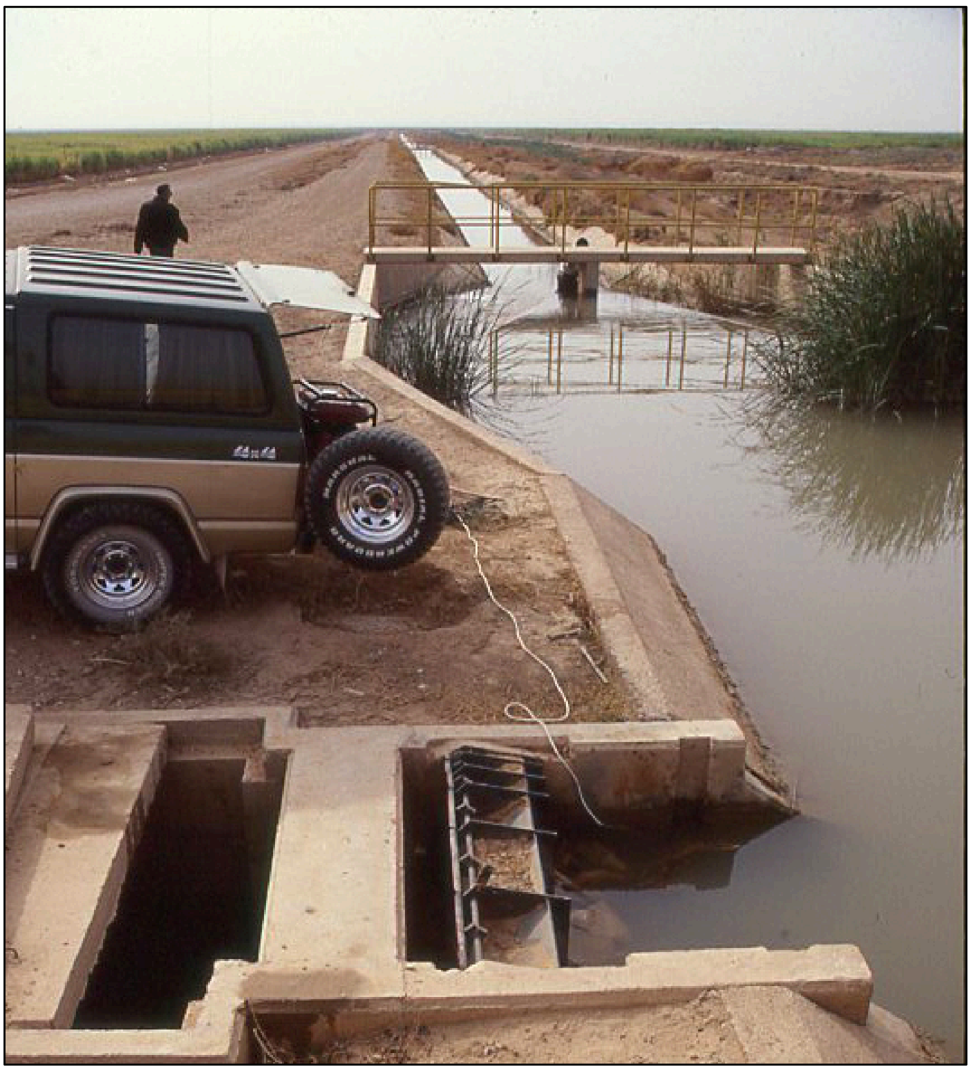
**Colour.** Overall colour is silvery to yellowish-white or brownish with the back grey-brown and the lower surfaces a lemon yellow or white. The lower jaw margin is a glossy yellow. The fish shown above may represent a spawning colouration, not seen in all specimens. The head beneath the eye and on the operculum along with the anterior flank are red, to orange to yellow. The pelvic fins can be a bright orange-red, the pectorals paler. Some fish have a less strong colour in the pelvic than in the anal fin. The anal fin is yellow, to orange or greenish, distally black and anteriorly most orange. The caudal fin has light orange to greenish tints. The dorsal fin is black with a yellow-tinged base becoming anteriorly reddish. In preserved fish, there is some concentration of pigment above and below each lateral line pore, scales on the back and upper flank are outlined with pigment, and there is some concentration of pigment into a few to a moderate number of diffuse spots on the uppermost flank and back midline. The leading edge of the dorsal fin is very dark (but can be light), dorsal fin membranes are dark, anal fin membranes also dark but to a lesser extent, and the caudal, pectoral and pelvic fins have pigment lining the rays. The peritoneum is black.

**Size.** **A**ttains 21.5 cm total length, or to 25.0 cm total length in Iraq (Al-Rudainy, 2008).

**Distribution.** This species is found in the Persis, Quwayq and Tigris-Euphrates basins. In Iran it is found in the Persis basin in the Dalaki River; and in the Tigris River basin in the Arvand, Chardoval, Dez, Gamasiab, Gangir, Godarkhosh, Jarrahi, Karkheh, Karun, Nahr Shavor, Shur, Simareh (Talkhab), Sirvan, Veisian and Zemkan or Zimakan rivers, the Niloufar Spring, Kermanshah, and the irrigation ditches of the sugar cane fields of Khuzestan (personal observations, 2000; CMNFI 2008-0169) (Abdoli, 2000; Nasri *et al.*, 2010, 2013, 2018, 2019; Dadashi *et al*., 2014; Taghavi Niya and Velayatzadeh, 2015; Khamees *et al*., 2019).

**Zoogeography.** Zoogeographical comments are under the genus above.

**Habitat.** This species is found in rivers, streams, springs, dams and canals but little is known of its environmental requirements. Collection data included capture in a concrete road underpass with slow current and encrusting vegetation.

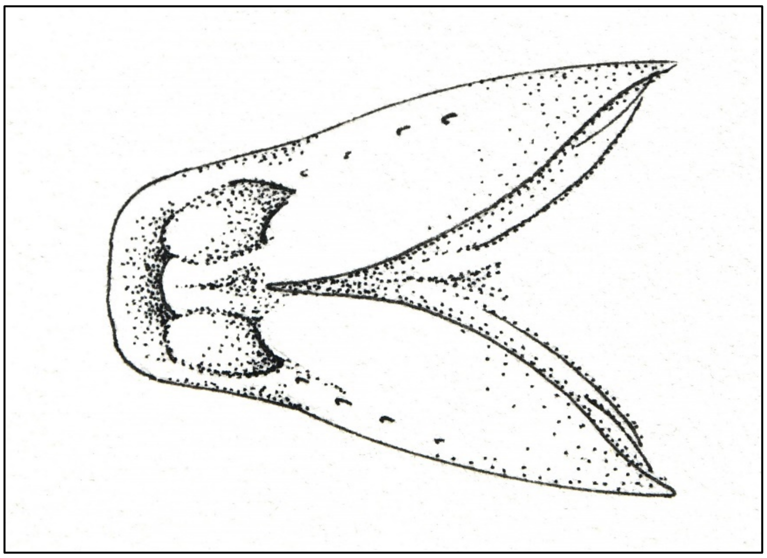


Habitat of *Cyprinion kais* (and *Arabibarbus grypus* and *Luciobarbus barbulus*), CMNFI 2008-0169, Khuzestan, irrigation ditch in sugar cane fields near Harmaleh, 27 November 2000, Brian W. Coad.

**Age and growth.** Esmaeili *et al*. (2014) gave a *b* value for 28 fish from the Tigris River basin, 9.8-15.9 cm total length, as 3.0. Keivany and Zamani-Faradonbe (2017b) examined 94 fish, 20.1-60.2 mm total length, from the Jarrahi River and found a *b* value of 3.16.

Alkan Uçkun and Gökçe (2015b) studied fish from Karakaya Dam on the Euphrates River of Turkey. The length-weight relationship was $W = 0.417FL^{3.02}$ and the age-length relationship was $L_t = 15.4(1-e^{-0.205(t + 0.503)})$. Male:female ratio was 1:1 and males attained age group 3 and females 4, with age group 1 most abundant.

**Food.** Gut contents were filamentous algae in the one specimen examined by me. Diet may be similar to *Cyprinion macrostomus*. Al-Rudainy (2008) gave aquatic insects and detritus for Iraq. Curiously, the mouth structure resembles that of the unrelated cutlips minnow, *Exoglossum maxillingua* (Le Sueur, 1817), a leuciscid from North America. This species feeds on insect larvae, with some molluscs and worms. Food is scraped from the bottom or poked out of crevices using the shovel-like lower jaw. Sand is also taken in and spat out, presumably after food items are extracted. The cutlips also picks out the eyes of other fishes in confined areas (Coad *et al*., 1995).



Ventral view of mouth of *Exoglossum maxillingua*,
CMNFI 1971-0249, 39.9 mm total length,
Canada, Québec, Rivière Chaudière (46º22'N, 70º55'W),
Sally Gadd @ Canadian Museum of Nature.

**Reproduction.** Ünlü (2006) gave age at first maturity as 2 years in the Turkish Tigris River with spawning over sand, stones and gravel in May-June. Alkan Uçkun and Gökçe (2015b) found fish from Karakaya Dam in Turkey had a mean fecundity of 295.1-1,255.2 eggs, mean oocyte diameter was 0.14-0.86 mm, length at maturity was 10.2 cm for females and 8.2 cm for males, and spawning occurred between June and August.

**Parasites and predators.** None reported from Iran.

**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** This species appears to be rare, or at least is rarely collected, in Iran. Taghavi Niya and Velayatzadeh (2015), however, evaluated fish species in the Shur River, Khuzestan where it was quite frequent. *Cyprinion macrostomus* is generally much more

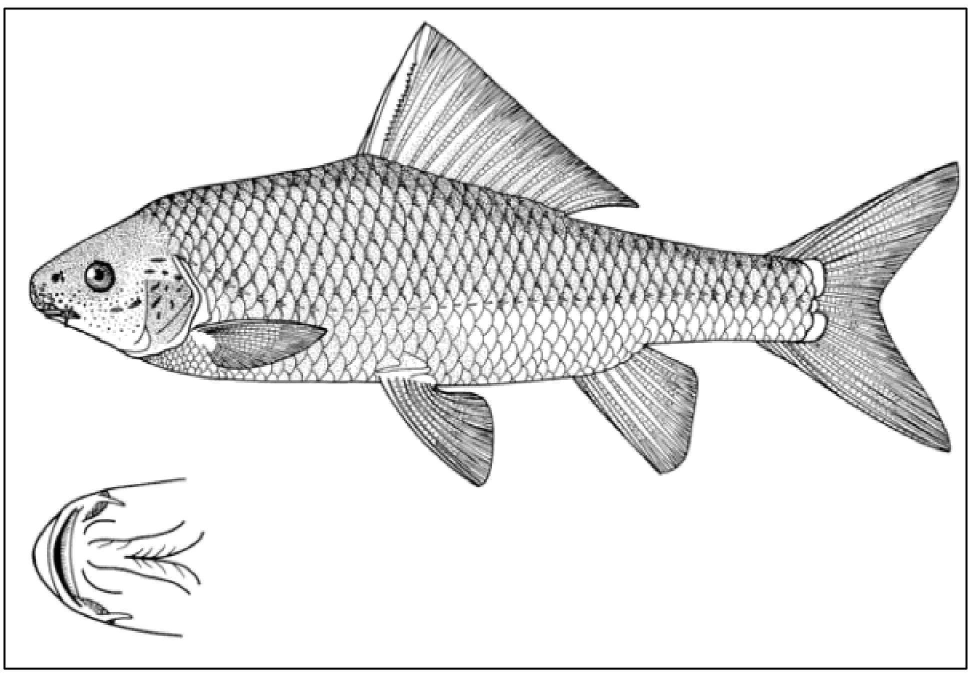
common and is taken in most seine hauls in streams and rivers. The distribution and population numbers are unknown. Endangered in Turkey (Fricke *et al*., 2007). Listed as of Least Concern by the IUCN (2015).

**Sources.** Type material:- *Cyprinion kais* (NMW 52801, 52802 and 52803) and *Cyprinion cypris* (NMW 52804, SMF 849, and possibly NMW 52800).

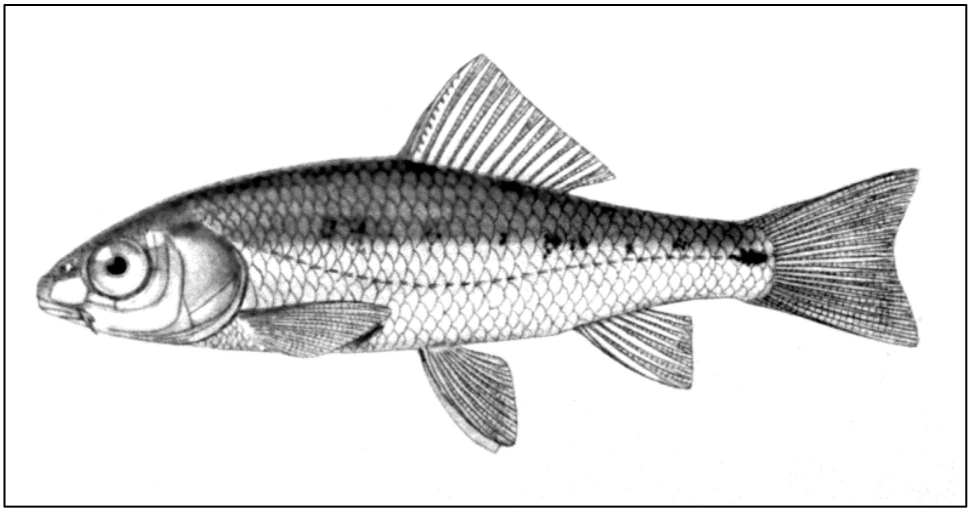
Iranian material:- CMNFI 1993-0141, 1, 66.3 mm standard length, Bushehr, Dalaki River (29º28'N, 51º15'E); CMNFI 2008-0169, 5, 80.4-98.2 mm standard length, Khuzestan, irrigation ditch in sugar cane fields (31º58'42"N, 48º31'07"E); ZSM 25715, 2, 34.1-65.3 mm standard length, Khuzestan, Dez River at Harmaleh (31º57'N, 48º34'E).

Comparative material:- BM(NH) 1920.3.3:50, 1, 83.6 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1920.3.3:94-115, 40, 65.3-92.4 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1931.12.21:3, 1, 129.8 mm standard length, Iraq, Mosul (36º20'N, 43º08'E); BM(NH) 1974.2.22:115-120, 5, 90.6-147.9 mm standard length, Iraq, Mosul (36º20'N, 43º08'E); BM(NH) 1974.2.22:1105, 1, 115.6 mm standard length, Iraq, Mosul (36º20'N, 43º08'E); BM(NH) 1974.2.22:1106, 1, 101.4 mm standard length, Iraq, Fao (29º58'N, 48º29'E); BM(NH) 1974.2.22:1214-1255 (in part), Iraq, Khalis (33º49'N, 44º32'E); BM(NH) 1984.4.18:30, 63.4 mm standard length, Iraq, Kut Hiwa (no other locality data); CMNFI 2008-0123, 5, 49.1-66.7 mm standard length, Iraq, Shatt al Arab near Qarmat Ali (30º34'N, 47º46'E); FMNH 51229, 1, 103.5 mm standard length, Iraq, Diyala River, 12 miles (= 19.3 km) east of Baghdad (ca. 33º25'N, ca. 44º35'E); FMNH 51230, 6, 42.9-60.5 mm standard length, Iraq, Diyala River, 12 miles (= 19.3 km) east of Baghdad (ca. 33º25'N, ca. 44º35'E); FMNH 51231, 2, 64.0-64.8 mm standard length, Iraq, Diyala River, 12 miles (= 19.3 km) east of Baghdad ca. 33º25'N, ca. 44º35'E).

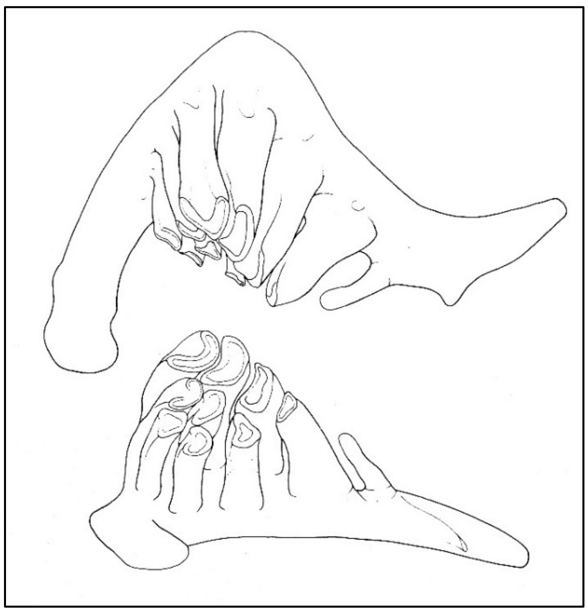
## *Cyprinion macrostomus*
Heckel, 1843



*Cyprinion macrostomus*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Cyprinion macrostomus*, ca. 3.3 cm total length, ZISP 24093,
Iraq, Mendeli (= Mandali), after Berg (1949).



*Cyprinion macrostomus*, pharyngeal teeth,
Freidhelm Krupp.

*Cyprinion macrostomus*, Hamadan, Haramabad, Gamasiab River, January 2010, Keyvan Abbasi.

*Cyprinion macrostomus*, Syria, Khabur River, Freidhelm Krupp.

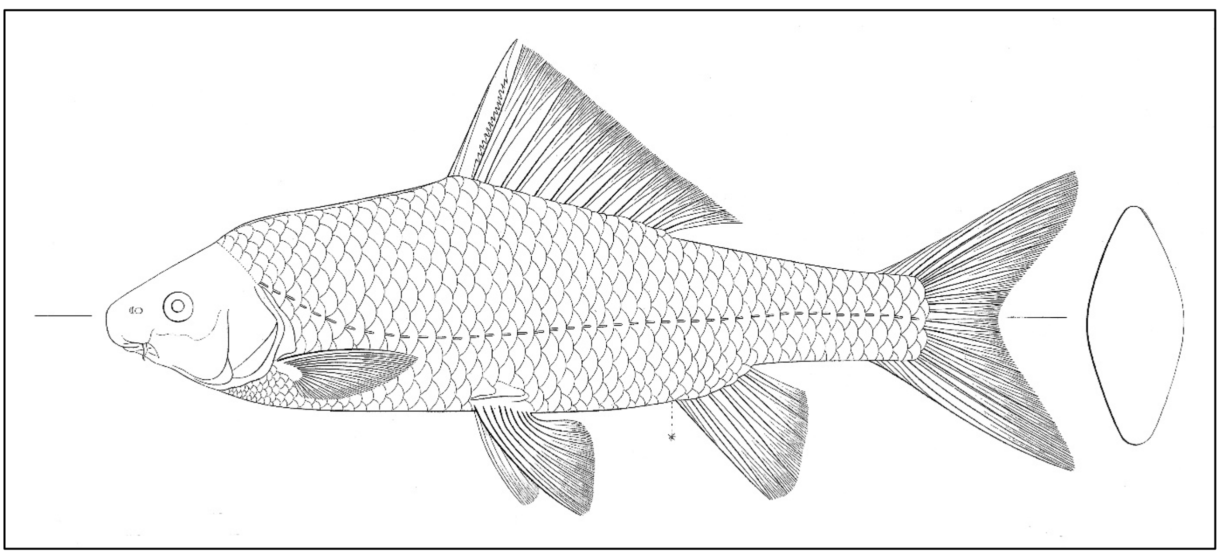
**Common names.** Botak, butok, lotak, lootak, lotak-e or butak-e dahan bozorg (= largemouth lotak, meaning of butak and lotak unknown); butak-e dehan (or dahan) buzorg in Khuzestan; galuk (Mokhayer (1981b); kanga fish in Bushehr Province (Bibak *et al*., 2013c) but this may be *C*. *tenuiradius* and the name could be from Kangal, the Turkish doctor fish locality); kapour (= carp), zanbour (= bee or wasp) in Khuzestan and Kohgiluyeh and Bowyer Ahmad provinces, zanbour dahan bozorg (= largemouth bee or wasp); doctor fish (Faghani Langroudi and Mousavi Sabet, 2018); tumbuek, possibly meaning hunting horn, from Heckel (1843b).

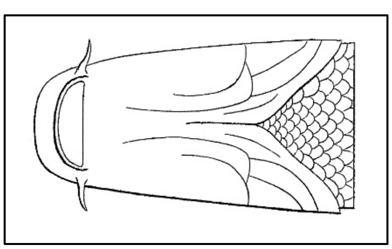
[Himriya sefra or hmarriya sefra or (humra meaning redness, red colouration, and safra meaning yellow, yellowish), surrah masih (from the Kurdish sura meaning red and masi meaning fish), benayne (from bunnayni, a diminutive of bunni), dunbuk kabir al-fam (from the Persian tombak and Arabic kabir meaning great and fam meaning mouth (all from Mikaili and Shayegh (2011)); bunni kaper, kais at Aleppo (= Haleb, Syria) but see above species (Heckel, 1843b); dombok or dumbek at Mosul meaning solid or compact flesh, a good source of food, according to Heckel (1843b); all preceding in Arabic; Beni balığı (in Turkish) and Karagöz (local name in eastern Turkey) (Kaya *et al*., 2016; Çiçek *et al*., 2020); bigmouth lotak or lutak,

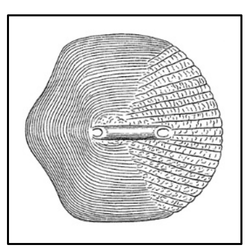
largemouth kingfish, largemouth lotak, large-mouthed barb, Tigris kingfish].

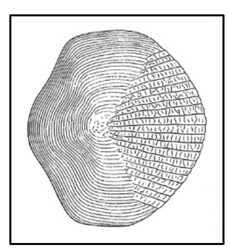
**Systematics.** Originally spelt *macrostomus* but correctly *macrostomum* according to Berg (1949) but the name is an indeclinable noun (*Catalog of Fishes*, downloaded 12 April 2018) so *macrostomus* is correct. *Cyprinion neglectus* Heckel, 1847 from the “Tigris bei Mossul” is a synonym (Krupp, 1985c; Banarescu and Herzig-Straschil, 1995). Howes (1982) considered that *Cyprinion tenuiradius* (*q.v.*) was only a “variant” of this species but did not examine any material. Berg (1949) places *C. kais* (*q.v.*) in the synonymy of this species along with *C. cypris* (see *C. kais*).

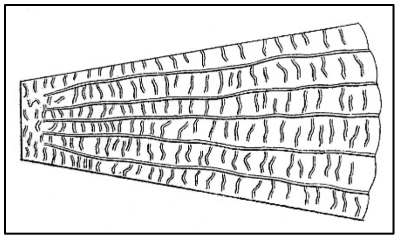
The type locality of *Cyprinion macrostomus* was given by Heckel (1843b) as “Aleppo” and “Mossul”. Krupp (1985c) listed five syntypes from Aleppo, 81-133 mm standard length in the Naturhistorisches Museum Wien (NMW 52805), the largest being selected as the lectotype (135.2 mm standard length in the Ichthyology Type Database, NMW (downloaded 9 July 2016)); see also Banarescu and Herzig-Strasil (1995); hence Aleppo is the type locality as designated by the publication of Banarescu and Herzig-Straschil (1995). A paralectotype, 159 mm standard length, from Mosul is under NMW 52503 (Ichthyology Type Database, NMW, downloaded 9 July 2016, a dried specimen). One syntype from Aleppo, 83 mm standard length, is in the Senckenberg Museum Frankfurt (SMF 70, formerly NMW; Eschmeyer *et al*. (1996) gave SMF 870) and four syntypes from Mosul, 58-124 mm standard length are in the Naturhistorisches Museum Wien (NMW 52806). My measurements are 81.9-135.1 mm standard length for NMW 52805 and 59.1-126.2 mm standard length for NMW 52806. The Rijksmuseum van Natuurlijke Historie, Leiden has one syntype under RMNH 2487, formerly NMW) and one syntype under RMNH 2488, formerly NMW). The catalogue in Vienna listed four specimens.





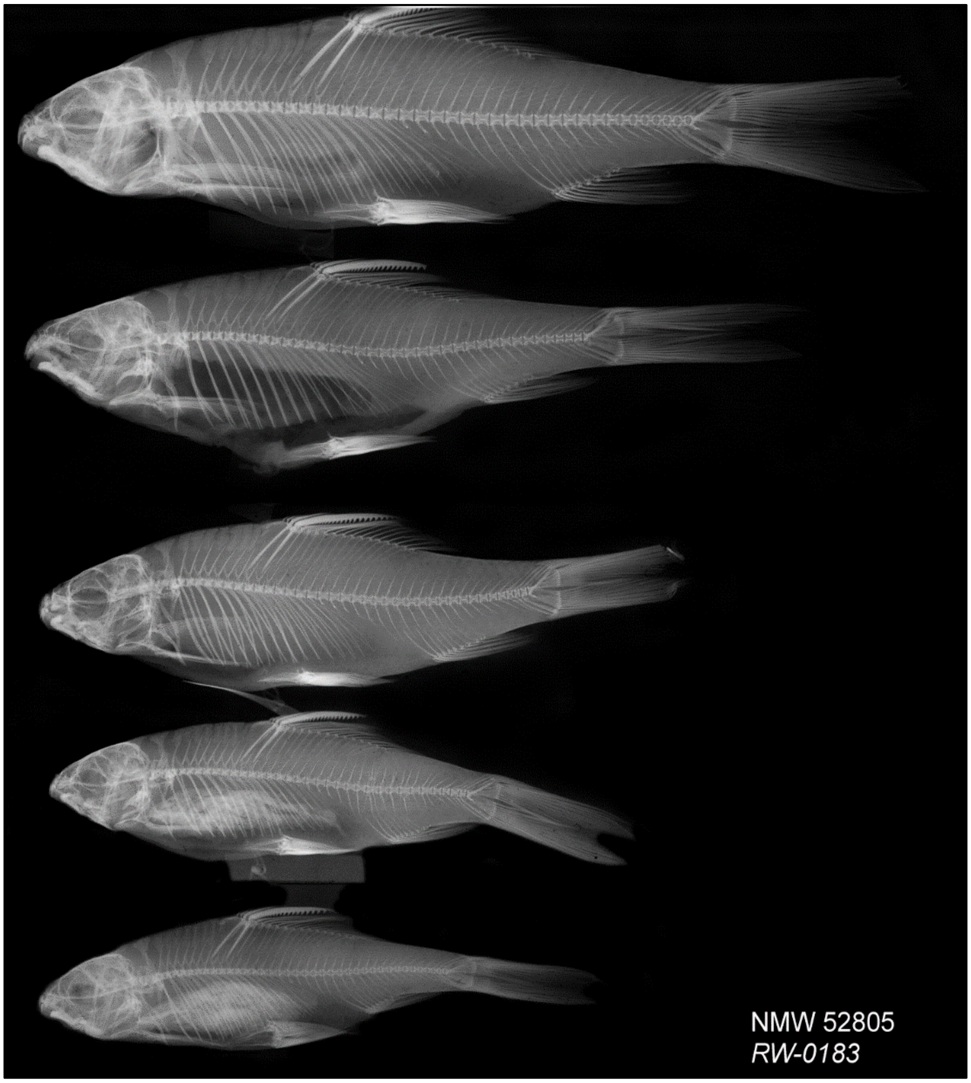






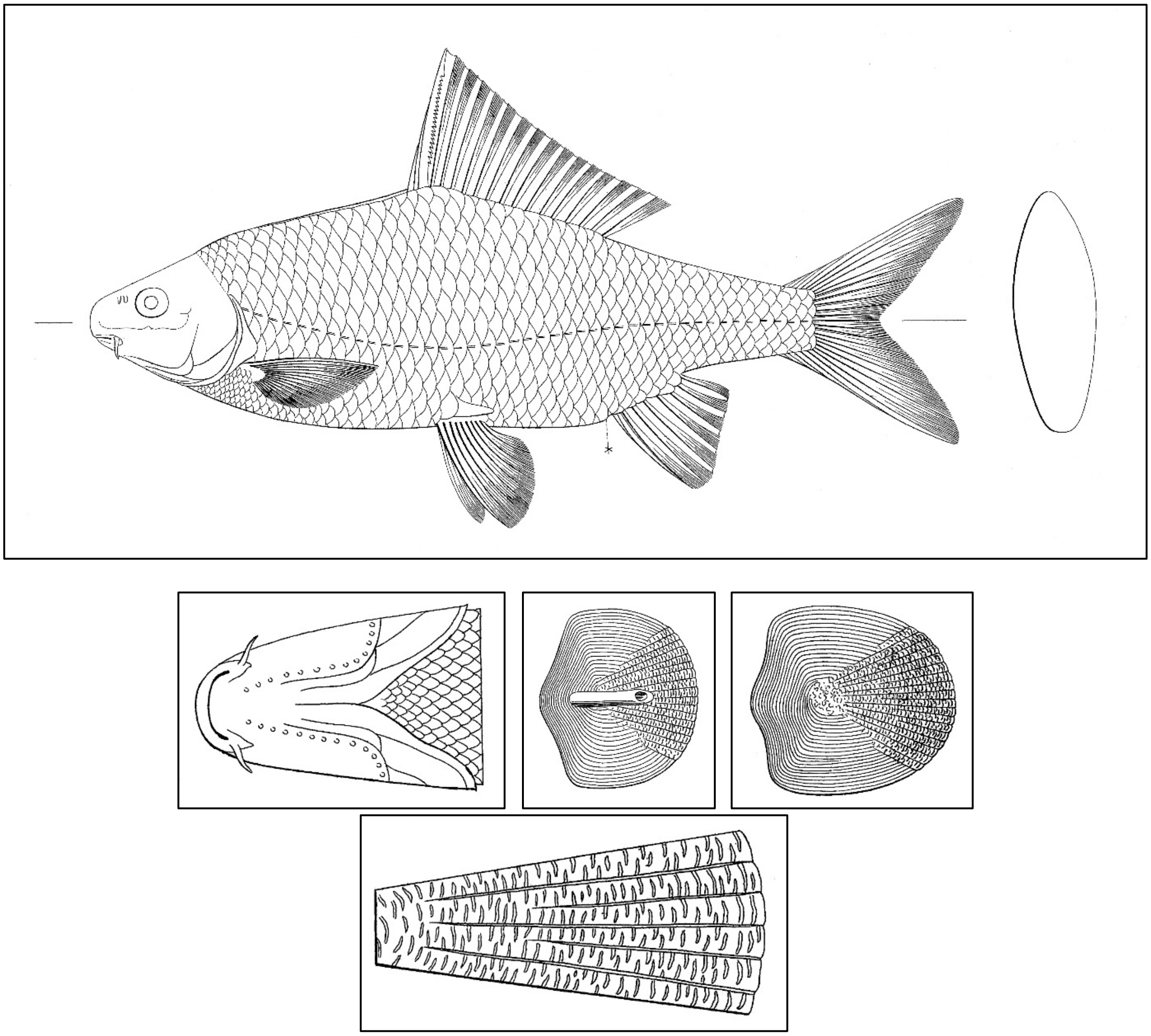
*Cyprinion macrostomus*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Cyprinion macrostomus*, lectotype and paralectotypes, NMW 52805,
Naturhistorisches Museum, Wien.




*Cyprinion macrostomus*, lectotype and paralectotypes, NMW 52805, Naturhistorisches Museum, Wien.

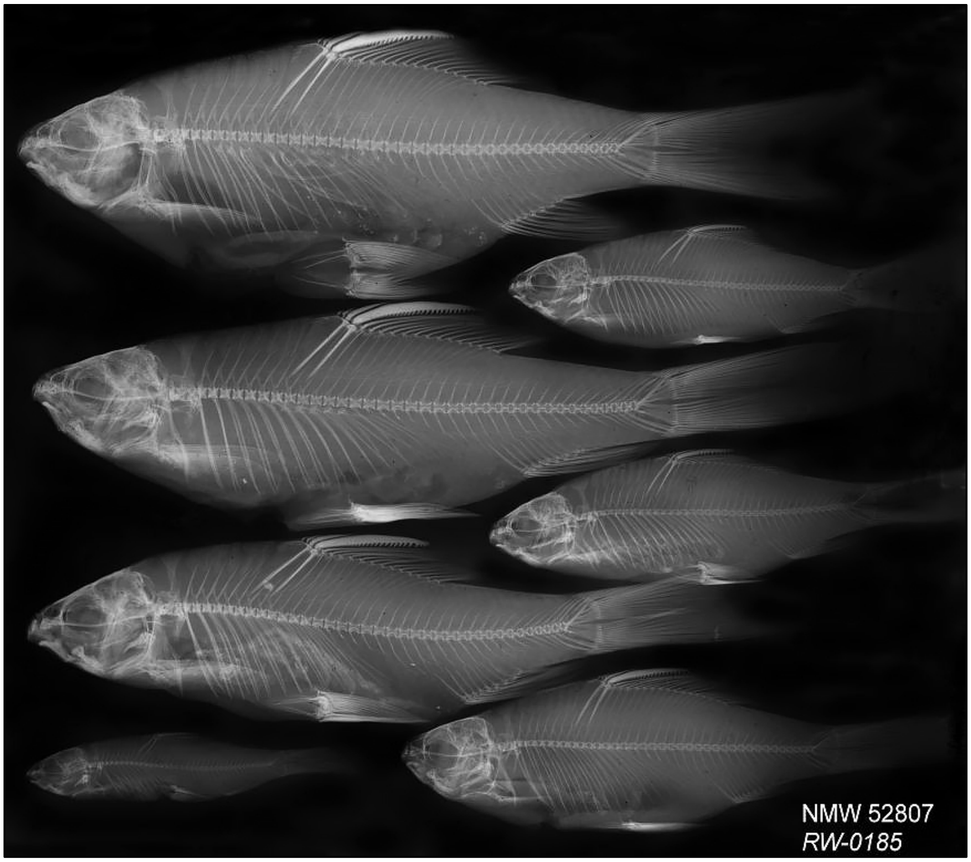
Seven syntypes of *Cyprinion neglectus* from Mosul measured 54-131 mm standard length (NMW 52807), the largest being selected as the lectotype (Krupp, 1985c). The ones photographed below are also captioned as paralectotypes by NMW and presumably 52807.1 is the lectotype. My measurements are 53.3-131.9 mm standard length (Banarescu and Herzig-Straschil (1995) have 53.1-128.2 mm standard length). All material was collected by Th. Kotschy in 1842 for Aleppo and 1843 for Mosul. The catalogue in Vienna listed only two specimens under this name.



*Cyprinion neglectus*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Cyprinion neglectus*, syntypes, NMW 52807, Naturhistorisches Museum Wien.


*Cyprinion neglectus*, syntypes, NMW 52807, Naturhistorisches Museum Wien.




*Cyprinion neglectus*, syntypes, NMW 52807, Naturhistorisches Museum Wien.

Moosavi *et al*. (2014) found a longer caudal length, a shorter head and more anterior position of the pectoral fin in some Tigris River basin populations in Ilam, attributing differences to phenotypic plasticity related to lower water current and shallower water depth. Nasri *et al*. (2013) clearly distinguished this species from *C. watsoni* on morphometric characters while noting that some may be due to environmental factors (a large river with high productivity versus a small stream with low productivity prone to drying in summer, respectively). Nasri and Eagderi (2013) compared this species with *C. watsoni* morphometrically, this species having a larger head and snout lengths, preventral distance, head depth, body depth, prepectoral length, and pectoral fin base length while *C. watsoni* had longer caudal peduncle length and depth and anal fin base length.

Daştan *et al*. (2012) examined the genetic diversity of this species in Anatolia and compared it with *C. kais*. Bilici *et al*. (2015) examined fish from the Tigris River basin in Turkey and found differences between localities in meristic and morphometric characters. Parmaksiz (2018) examined fish from the Turkish Euphrates and Tigris rivers and described their genetic diversity using mitochondrial DNA.

**Key characters.** Distinguished from *C. kais* by mouth and dorsal fin ray characters as described under that species, and by having more gill rakers and a longer and more coiled intestine (Kafuku, 1969). The dorsal fin origin is in front of that of the pelvic fins (Heckel, 1847a). See discussion under *C. tenuiradius* for distinction from that taxon.

**Morphology.** The body is compressed and moderately deep, being deepest at the origin of the dorsal fin. The predorsal profile is slightly convex to straight. The caudal peduncle is

compressed and moderately deep. There is a predorsal ridge. The dorsal profile of the head is straight and a continuation of the predorsal profile, leading to a rounded snout. The eye lies in the anterior half of the head. The lips are moderately thick where developed. The barbel is thin and extends back as far as the mid-eye. The dorsal fin spine is strong with large denticles extending almost to the tip (see x-ray under *C. tenuiradius*). The dorsal fin margin is straight to slightly emarginate, often being markedly emarginate at the beginning and straight over the rest of the margin. The origin of the dorsal fin is slightly or clearly anterior to the level of the pelvic fin origin. The depressed dorsal fin reaches back level with the anterior or middle of the anal fin. The caudal fin is deeply forked with slightly pointed or rounded tips, the lower tip being more rounded. The anal fin margin is straight or rounded and the fin extends back to the caudal fin base or falls short. The pelvic fin margin is straight to rounded and may extend back as far as the anus in some fish. The pectoral fin margin is straight to falcate and the fin does not extend back to the pelvic fin origin.

The mouth is subterminal, usually transverse or slightly arched, and usually has a horny covering. Small fish have a crescentic mouth or u-shaped mouth. A wide range of mouth arching is seen in fish of varying sizes and even in fish of the same size and locality of capture. Banarescu and Herzig-Straschil (1995) noted that the syntypes of *Cyprinion neglectus* have a mouth arch that is more curved and not as wide, somewhat intermediate between *C. macrostomus* and *C. kais*, being closer to the former. The variation is attributed to the material possibly being from some tributary of the Tigris River, or from isolated ponds, where introgression with *C. kais* took place. It may well be that variation in mouth shape is more marked than limited sample sizes would indicate. Certainly, in smaller fish, e.g., in 20 specimens of *C. macrostomus* (38.5-54.0 mm standard length selected from CMNFI 1979-0290, 1979-0361, 1979-0364, 1979-0373, 1979-0374) examined by me from Iran, values for mouth width and depth as measured in Banarescu and Herzig-Straschil (1995) are not as clear cut and there is a variable developmental gradient in mouth shape. Mouth “height” as a percentage of width was 29.2-53.8 and width as a percentage of head length was 22.1-36.6. Banarescu and Herzig-Straschil (1995) gave “height” as 19-31% of width and width as 26-44% head length for *macrostomus* and 48-80% and 13.5-22.0% respectively for *kais*. Large *macrostomus* and *kais* (>100 mm SL) can be distinguished on mouth shape but not smaller specimens which bridge the gap between the two species. In small fish, the upper lip is not covered with a fold of the snout as in large fish.

Dorsal fin with 4 unbranched and 12-17 branched rays (usually 14-15 according to Banarescu and Herzig-Straschil (1995) but 77% of fish in Iran are 13-14, see below and Nasri *et al*., 2018)). The anal fin has 3 unbranched and 6-8, usually 7, branched rays. In Iranian specimens, 96.1% of 127 fish have 7 rays, the remainder 6 rays. Pectoral fin branched rays are 10-17, usually 15-17 (11-12 in Nasri *et al*., 2018)), and pelvic fin branched rays 6-9, usually 7-8. Lateral line scales 33-45 (usually 41-44 according to Banarescu and Herzig-Straschil (1995) but a broader range in Iran, see below). The breast is covered with scales. The pelvic axillary scale is very elongate. Scales are squarish, being deeper than long, often with parallel dorsal and ventral margins (or rounded margins). The anterior margin has a marked central protuberance and the posterior margin is rounded. Radii are numerous on the posterior field and circuli are fine and numerous. The posterior field circuli break into tubercles. The focus is subcentral anterior. Kontaş *et al*. (2020) gave details of scale morphology in fish from Sivas, Turkey, including differences between body regions and between young and adult fish. The area below the dorsal fin was recommended as the best for descriptive purposes (used

throughout the current work) and for ageing purposes. Total gill rakers number 16-17, on the lower arm 12-16, in literature but a much wider range in total rakers in Iran (see below where it is 13-21). Rakers are short and only touch the raker below or a little further when appressed. Pharyngeal teeth are 2,3,5-5,3,2, 2,3,4-4,3,2, and variations on 4 or 5 main row teeth. Teeth are spatulate with broad, flattened crowns. The tips of teeth are slightly hooked in small fish. The most anterior tooth in the main row may be very small or absent (or incompletely ossified and hard to distinguish). The gut is very elongate with complex coils, less developed in young but still evident. Total vertebrae number 37-40 (Jouladeh-Roudbar *et al*., 2020). The lectotype and paralectotypes, NMW 52805, have 41 and 40(2) or 41(1) respectively, one paralectotype not counted because of fusions. The three largest syntypes of *C. neglectus*, NMW 52807, all have 40 total vertebrae. Chromosome number is 2n = 48 (Gaffaroğlu and Yüksel, 2004) or 2n = 50 (Yüksel and Gaffaroğlu, 2008a) for Turkish specimens, 2n = 50 according to Nasri *et al*. (2015) for fish from the Godarkhosh River in Ilam.

Kontaş *et al*. (2020) gave details of otolith morphology in fish from Sivas, Turkey with no major differences between juveniles and adults but the asteriscus shape differed between the left and right.

Meristic values for Iranian fish from the Tigris River basin are:- dorsal fin branched rays 12(4), 13(43), 14(52), 15(26) or 16(3) (mean = 13.9, S.D. = 0.861), pectoral fin branched rays 14(3), 15(44), 16(57) or 17(25) (mean = 15.8, S.D. = 0.771), pelvic fin branched rays 7(7), 8(121) or 9(1) (mean = 8.0, S.D. = 0.246), lateral line scales 33(3), 34(1), 35(12), 36(11), 37(3), 38(11), 39(29), 40(31), 41(25), 42(2) …. or 45(1) (mean = 38.8, S.D. = 2.211), total gill rakers 13(3), 14(8), 15(15), 16(23), 17(15), 18(24), 19(17), 20(14) or 21(6) (mean = 17.3, S.D. = 2.022), pharyngeal teeth 2,3,5-5,3,2(17), 2,3,4-5,3,2(8), 2,3,5-4,3,2(3) or 2,3,4-4,3,2(2), and total vertebrae 38(1), 39(1) or 40(1).

**Sexual dimorphism.** Mature males have large tubercles on the snout in a broad band below the nostril level, extending back under the eye and breaking up into a few tubercles on the operculum. There is a large tubercle between the nostril and the eye. Fine tubercles are scattered over the top of the head. Three tubercles are found in rows on the first pectoral fin branched ray and very strong tubercles line each anal fin branched ray in single file. The anterior pelvic fin rays have the occasional 1-2 tubercles or a row of tubercles. Dorsal and caudal fin rays have fine tubercles, much smaller than those on the anal fin. Mid and posterior flank scales have 1-3 small tubercles, variably arranged on the exposed scale (CMNFI 1979-0283, 6 July 1977, 144.0 mm standard length).

**Colour**. The back is bluish-grey to bluish-black or brown, flanks silvery, silvery-yellow or silvery-brown and the belly whitish with silvery tints. The upper head is light brown. Scales are outlined with dark pigment and the anterior exposed scale base is darkened. The cleithrum area is pink or orange in some fish with pink or orange spots on up to 5 rows of flank scales but mostly along the anterior lateral line. Fish from a saline stream in Khuzestan had a pale-pink cleithrum and lateral line spots. There is a reddish-yellow spot at the base of the pectoral and pelvic fins. The pectoral, pelvic, anal and caudal fins are yellowish to pinkish or orange proximally and blackish distally. The dorsal fin has a narrow, yellow stripe at the base and the rest of the fin is black. The rays of the dorsal and anal fins may be black in contrast to the pale membrane. The cartilaginous lower jaw is reddish-yellow to orange. The iris is slightly yellow. Small live fish are silvery overall with a white belly and olive back, the pectoral and pelvic fins slightly orange-yellow and other fins greyish although all fins may be hyaline. The peritoneum is black. Fish in ice water are silvery with scales outlined by dark pigment and with a dark area

at the exposed anterior part of each scale. Pectoral and pelvic fins are slightly orange-pink but all fins are hyaline. The anal fin is darker distally and the dorsal and caudal fins are hyaline but darker overall than the other fins. The peritoneum is dark brown to black.

Small preserved fish have an indistinct blotch at the caudal fin base and a similar blotch on the back at the base of the spine in the dorsal fin. In very small fish, these blotches are more distinct and there are 4-7 irregular blotches on the mid-flank above the lateral line and three blotches at the dorsal fin base. Development of blotches is individually variable, some fish being almost immaculate while in others the blotches extend vertically as bars as far as the back.

**Size.** Reaches 19.3 cm standard length (Krupp, 1985c) and 20.0 cm standard length (Kaya *et al*., 2016).

**Distribution.** This species is found in the Orontes (= Asi), Quwayq and Tigris-Euphrates basins. In Iran, it is found in the Tigris River basin (see under *C. tenuiradius* for a somewhat artificial distributional distinction with this species) including the Abloun, Abshar, A`la, Alvand, Arvand, Avan Abbas, Bahmanshir, Balarud, Bazoft, Beshar, Bohlol, Chameshk, Chardavol, Dez, Dinorab, Do-Ab, Doveyrich, Eivashan (= Eushan), Gahar, Gamasiab, Gangir, Gaveh, Godarkhosh, Haramabad, Harud, Homeil, Jagiran, Jarrahi, Kahank, Kangir, Kangvar Kohne, Karkheh, Karun, Kashkan, Kerend, Khersan, Khorram (Khorramabad), Marun, Meymeh, Murani, Qareh Su, Qeshlaq, Qolalb, Qopal, Ravand, Sar Cham, Semeh, Sezar, Shate Neisan, Shavor, Shur, Sikan, Silakhour, Simareh, Sirvan, Talkhab, Tangab and Zard rivers, the Hawr al Azim, the Bisheh-Dalan, Gamasiab and Haramabad wetlands in Hamadan Province, sarabs near Kermanshah, and the Dez Dam (Berg, 1949; Abdoli, 2000; Eskandari *et al*., 2007; Nasri, 2008; Sadeghinejade Masouleh, 2008; Abbasi *et al*., 2009; Biokani *et al*., 2011; Minabi *et al*., 2012; Biukani *et al*., 2013; Nasri *et al*., 2013, 2018, 2019; Pirani *et al*., 2013; Dadashi *et al*., 2014; Khoshnood, 2014; Marammazi *et al*., 2014; Moosavi *et al*., 2014; Ramin *et al*., 2014; Tabiee *et al*., 2014; Abdolhahi, 2015; Pirshaeb et al., 2015; Taghavi Niya and Velayatzadeh, 2015; Zamaniannejad *et al*., 2015; Alizadeh Marzenaki *et al*., 2016; Taghiyan *et al*., 2016; Keivany and Zamani-Faradonbe, 2017b; Sadeghi Nejadmasouleh and Darvishian, 2017; Darvishi *et al*., 2018; Faghani Langroudi and Mousavi Sabet, 2018; Nasri and Eagderi, 2018; Sadeghinejad Masouleh and Abbasi, 2018a; Fatemi *et al*., 2019; Hasankhani *et al*., 2019; Khamees *et al*., 2019; Nasri, 2021; K. Abbasi, see photograph above).

Berg (1949) recorded this species from several localities (here with amended spellings indicated by * but similar to the original, otherwise indicated by an = sign if changed or uncertain) on the Khuzestan plain in the Karun River basin from *Cheshmeh Rogan (probably Rowghani) between *Qaleh-ye Tol and Dzhoru or Dzharu, Kulihan between Shushtar and *Qaleh-ye Tol, Agulyashker (= Ab-e Lashkar) between Shushtar and *Qaleh-ye Tol and Al Khorshir 10 km from *Qaleh-ye Tol (Karun River basin in the Tigris River basin).

Vossoughi (1998) reported this species from the western Hamun-e Jaz Murian basin based on fishes with 13-15 dorsal fin branched rays, much higher than for *C. watsoni*, the taxon to be expected in this area, possibly an introduction if rays were correctly counted.

**Zoogeography.** Zoogeographical comments are under the genus above.

**Habitat.** This species is found in rivers, streams, lakes, dams, lagoons, ponds, springs, marshes, canals, jubes (= irrigation ditches) and gravel pits. Stream habitats are illustrated below. It is the most abundant species (31.3%) in the Godarkhosh River, Ilam (Pirani *et al*., 2013). This is the commonest species in catches in southwestern Iran, followed by *Garra rufa*. In areas under human influence in Lorestan, such as the lower reaches of rivers and near cities,

it exceeds 80% in numbers in catches. In the Kashkan River, Lorestan this species had the second highest frequency after *Capoeta trutta*, 1,308 fish out of 4,207 caught comprising 18 species (Sadeghinejad Masouleh and Darvishian, 2017). Sadeghinejad Masouleh and Abbasi (2018a) found this species comprised 4.25% of fish caught in the Simareh River out of 22 species.

Al-Habbib and Al-Habbib (1979) have demonstrated experimentally for a sample from Nawaran Spring north of Mosul, Iraq that this species could survive temperatures up to about 37°C. At an acclimation temperature of 30°C, the $LT_{50}$ increased to 39.3°C. Akpinar and Aksoylar (1989) and Akpinar (1999) reported this species from the Kangal Thermal Spring, Sivas, Turkey at a constant temperature of 35°C.

Habitat of *Cyprinion macrostomus* (and *Garra rufa*), CMNFI 2008-0167, Khuzestan, stream above Diuni Darreh, 26 November 2000, Brian W. Coad.


Habitat of *Cyprinion macrostomus*, CMNFI 2008-0120, Khuzestan, Zard Rud at Bagh-e Malek, 20 September 1995, Brian W. Coad.

**Age and growth.** Khoramian *et al*. (2014c) gave a total length and weight relationship for 115 Karkheh River fish as LogW = -1.62 + 2.84LogL indicating negative allometric growth. The condition factor was 0.789. Faghani-Langroudi *et al*. (2014) examined 319 fish, 9.4-16.2 cm standard length, from a stream in the Gamasiab River basin for length-weight relationships and found *b* values of 3.416 for males, 3.318 for females and 3.442 for sexes combined, all positively allometric. Faghani Langroudi and Mousavi Sabet, (2018) gave an age range of $1^+$ to $5^+$ years for 316 Gamasiab River fish, 5.2-19.8 cm total length, with most age 2+ (28.5%) and 3+ (34.5%) years. Nowferesti *et al*. (2014) found a *b* value of 3.1 for 18 fish, 2.3-10.0 cm total length, from Dinvar. Esmaeili *et al*. (2014) gave a *b* value for 70 fish, 4.86-20.4 cm total length, from the Tigris River basin, 4.86-20.4 cm total length, as 3.14. Keivany and Keivany and Zamani-Faradonbe (2017b) examined 56 fish, 19.5-99.2 mm total length, from the Jarrahi River and found a *b* value of 3.21. In the Kashkan River, Lorestan this species had

age groups 1 to 5 years with age 3 the most common (Sadeghinejad Masouleh and Darvishian, 2017). Valikhani *et al*. (2020) combined fish from the Shadegan Wetland and the Dez and Karkheh rivers and reported a *b* value of 3.02 (isometric growth) and a condition factor of 3.55 for 181 fish, 4.0-16.5 cm total length.

Maximum age reported for a population in the Al-Nibaey Lakes near Baghdad was $7^+$ years. Growth was slow and there was no difference in growth between males and females, although the habitat was not ideal for these fishes. Females tended to be slightly heavier than males of the same length especially in older fish. The length-weight relationship was $W = 0.027\ L^{2.67}$ for both sexes, $W = 0.028\ L^{2.65}$ for males and $W = 0.020\ L^{2.78}$ for females. Maturity was attained at 10.0-11.1 cm, corresponding to age group 2 (Allouse *et al*., 1989). The length-weight equation for commercially caught fish in the Tigris River was log W = 2.884 log L-4.623, condition factor was 1.15-1.47 (mean 1.28) and fish were immature up to age $2^+$ (Al-Nasiri, 1991). Alkan Uçkun and Gökçe (2015b) studied fish from Karakaya Dam on the Euphrates River of Turkey. The length-weight relationship was $W = 0.725FL^{2.92}$ and the age-length relationship was $L_t = 15.0(1-e^{-0.212(t + 0.407)})$. Male:female ratio was not significantly different from 1:1 and males and females attained age group 4, with age group 1 most abundant.

**Food.** Marammazi *et al*. (2014) found fish from the Sezar River in Lorestan fed on periphyton including *Navicula*, *Cymbellla*, *Diatoma* and *Nitzschia* as main items and a further 20 genera as subsidiary or accidental food items.

Major food items in the Baghdad study were of plant origin with occasionally some chironomid larvae, copepods and cladocerans. Khan (1988) found for fish from near Sulaymaniyah, Iraq that diatoms and decayed organic matter were the main foods, with some green algae. Zooplankton were thought to be accidental food items. Guts contained mud and sand, evidence of a bottom feeding habit. Feeding increased at the start of the breeding season. The horny lower jaw covering was used to scrape algal food off hard bottom objects.

**Reproduction.** Iranian material showed minute but developing eggs in a 45.7 mm standard length fish caught on 31 January 1978 (CMNFI 1979-0387) and specimens caught on 5 July 1977 (CMNFI 1979-0278) had eggs 1.4 mm in diameter. A male, 70.1 mm standard length from the 31 January sample, had tubercles on the snout and anal rays so tubercles developed quite early and in small fish. A fish caught on 20 September 1995 (CMNFI 2008-0120) also showed tubercles around the snout. A small fish caught on 26 January 1978 (CMNFI 1979-0356) 22.0 mm standard length was presumably the young from the previous season and so showed slow growth or was evidence of a prolonged or late spawning season.

Faghani Langroudi and Mousavi Sabet (2018) examined 316 fish from the Gamasiab River, and found a significantly different (female:male sex ratio of 1:1.31, mature females and males were longer than 10.8 cm and 9.4 cm total length ($2^+$ and $1^+$ in age, respectively), the gonadosomatic index ranged between 0.09-2.94% and 1.70-15.53% for males and females respectively, gonad indices showed spawning took place from late May to mid-August when the water temperature was 16-24°C, some fish showed a secondary development of ovaries from late August to mid-September when some fish were ready to spawn, average diameter of oocytes ranged from 0.2 mm to 1.7 mm in the spawning season, average absolute and relative fecundity were 3,642.51 eggs (range 958-5,629 eggs) and 55.04 eggs/g body weight (range 38.1-67.9 eggs/g) respectively, and absolute fecundity was significantly related to body weight and ovary weight.

Near Baghdad, most fish were mature by April, the gonads occupying about one-third

of the body cavity. Ovaries were orange to yellowish and testes milky white. Spawning occurred principally in May and June, with some in early July, but by July most fish were spent. Al-Rudainy (2008) gave a spawning season of May and June in Iraq on gravel beds in shallow water with fast current. Maturity was attained there at 2-3 years, 15 cm length and 50 g weight. Alkan Uçkun and Gökçe (2015b) found fish from Karakaya Dam in Turkey had a mean fecundity of 313.0-1,647.08 eggs/fish, mean oocyte diameter was 0.13-1.34 mm, length at maturity was 9.9 cm for females and 8.2 cm for males, and spawning occurred between June and August.

**Parasites and predators.** Gussev *et al*. (1993a) described a new species of monogenean from this fish species in the Karun River, *Dactylogyrus cyprinioni*, and Jalali (1992) a new species of monogenean, *Dogielius molnari*, in the Dez River, both in Khuzestan. Jalali *et al*. (1995) described another new species of monogenean, *Dactylogyrus pallicirrus*, from fish taken in the Dez River near Ahvaz. Mortezaei *et al*. (2007) reported the nematode *Rhabdocona denudata* from this fish in Shadegan Marsh, Khuzestan. Gholamifard *et al*. (2010) reported papillomatosis (skin warts) in this species. Peyghan *et al*. (2018) recorded *Ichthyophthirius multifilis*, *Myxobolus* sp., *Dactylogyrus* sp. and *Diplostomum spathaceum* from this fish in the Dez River. Moumeni *et al*. (2020) recorded the zoonotic *Clinostomum complanatum* from this fish in Iran.

**Economic importance.** Nasri *et al*. (2018) stated that members of *Cyprinion* are used for food in western Iran, presumably this species. Al-Mehdi and Khan (1984) reported it to be important in riverine and culture fisheries in northern Iraq.

Ündar *et al*. (1990) identified this species and *Garra rufa* as the “doctor fish” of the Kangal hot spring in Turkey (Timur *et al*., 1983; Warwick and Warwick, 1989; Kürkçüoğlu and Öz, 1989; and various newspaper and television reports). High water temperatures reduce the amount of plankton available as fish food and the fish nibble away infected skin of humans who bathe in these waters. The fish is known as “striker” (and *Garra rufa* as “licker”) from its behaviour in the spa pools. The healing properties are linked to the high level of selenium (1.3 p.p.m.) in the water, selenium being beneficial in some skin diseases, and possibly to UV light. The fish facilitate the action of the selenium and UV light by softening and clearing away psoriatic plaque and scale, exposing the lesions to the water and sunlight. However, some lesions are made worse and the fish could cause some new ones.

**Experimental studies.** Velayatzadeh and Tabibzadeh (2011) examined fish from the Karun River for cadmium, lead and mercury in the muscle and liver tissue. Liver levels were higher than muscle levels and muscle levels were within acceptable international standards. Pirshaeb *et al*. (2015) found high levels of chromium and vanadium, exceeding international standards, in muscle tissue of fish from the Gharasou (= Qareh Su) in Kermanshah from industrial and municipal wastewater. Minabi *et al*. (2012) found that some body biochemical parameters (moisture, protein and fat but not ash) varied between summer and autumn, presumably related to food abundance, in fish from the Sezar River in Lorestan Province. The haematology of this species from Sarao Subhana Agha near Sulaymaniyah was examined by Al-Mehdi and Khan (1984).

**Conservation.** This species is widely distributed in southern areas, particularly Khuzestan, and does not appear to be under threat other than that suffered by all species by pollution and water abstraction. Endangered in Turkey (Fricke *et al*., 2007). Listed as of Least Concern by the IUCN (2015).

**Sources.** Type material:- *Cyprinion macrostomus* (NMW 52805, 52806) and *Cyprinion*

*neglectus* (NMW 52807).

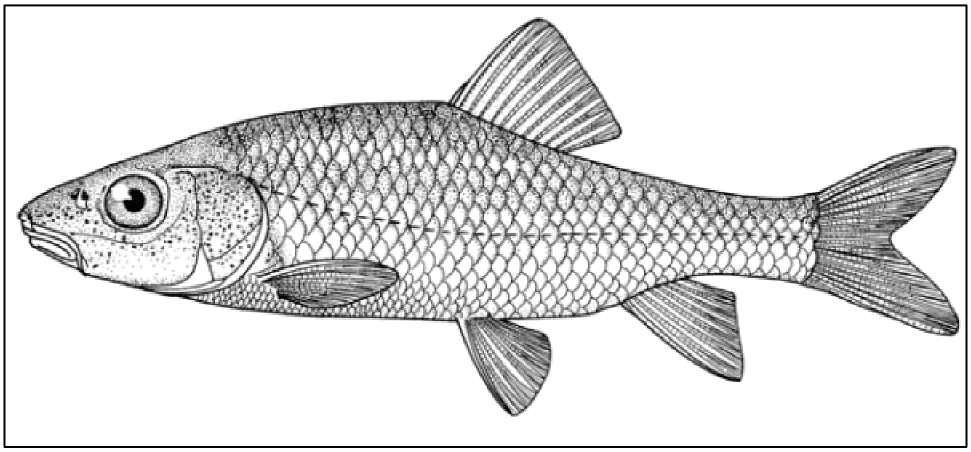
Iranian material:- CMNFI 1979-0268, 13, 92.2-122.4 mm standard length, Lorestan, Dez or Karkheh drainage between Nowqan and Khorramabad (no other locality data); CMNFI 1979-0269, 4, 104.7-110.6 mm standard length, Lorestan, Dez or Karkheh drainage between Nowqan and Khorramabad (no other locality data); CMNFI 1979-0270, 10, 85.5-122.4 mm standard length, Lorestan, Kashkan River drainage outside Khorramabad (33º26'N, 48º19'E); CMNFI 1979-0271, 3, 100.7-144.8 mm standard length, Lorestan, river in Kashkan River drainage (33º39'N, 48º32'30"E); CMNFI 1979-0273, 9, 36.9-69.8 mm standard length, Lorestan, Kashkan River drainage 5 km from Khorramabad (33º26'N, 48º19'E); CMNFI 1979-0274, 14, 24.8-53.9 mm standard length, Lorestan, river in Kashkan River drainage (33º27'N, 48º11'E); CMNFI 1979-0275, 2, 142.4-165.0 mm standard length, Lorestan, Kashkan River 2 km from Ma'mulan (33º25'N, 47º58'E); CMNFI 1979-0276, 1, 124.7 mm standard length, Lorestan, Chameshk River (ca. 33º19'N, ca. 47º53'30"E); CMNFI 1979-0277, 2, 90.3-94.9 mm standard length, Lorestan, Kashkan River drainage (33º30'N, 47º59'30"E); CMNFI 1979-0278, 4, 93.5-114.1 mm standard length, Lorestan, Kashkan River drainage (33º34'N, 48º01'E); CMNFI 1979-0279, 9, 100.3-149.4 mm standard length, Lorestan, Khorramabad River (33º37'N, 48º18'E); CMNFI 1979-0283, 5, 93.0-144.0 mm standard length, Kermanshah, river in Qareh Su drainage (34º21'N, 47º07'E); CMNFI 1979-0287, 1, 112.6 mm standard length, Kermanshah, Cheshmeh Javari 2 km from Ravansar (ca. 34º42'N, ca. 46º40'E); CMNFI 1979-0288, 1, 94.3 mm standard length, Ilam and Poshtkuh, Gangir River at Juy Zar (33º50'N, 46º18'E); CMNFI 1979-0289, 4, 91.5-110.8 mm standard length, Kermanshah, river in Diyala River drainage (34º28'N, 45º52'E); CMNFI 1979-0290, 11, 49.3-133.0 mm standard length, Kermanshah, river in Qasr-e Shirin (34º31'N, 45º35'E); CMNFI 1979-0291, 15, 15.0-91.2 mm standard length, Kermanshah, river in Diyala River drainage (34º24'N, 45º37'E); CMNFI 1979-0350, 18, 15.8-36.1 mm standard length, Khuzestan, Marun River near Marun (30º39'30"N, 50º02'E); CMNFI 1979-0355, 1, 38.7 mm standard length, Khuzestan, stream tributary to Karun River at Salmaneh (30º35'N, 48º22'E); CMNFI 1979-0356, 1, 22.0 mm standard length, Khuzestan, Karkheh River drainage stream at Hoveyzeh (31º27'N, 48º04'E); CMNFI 1979-0360, 2, 19.1-22.0 mm standard length, Khuzestan, canal branch of Karkheh River (31º40'N, 48º35'E); CMNFI 1979-0361, 3, 27.4-53.5 mm standard length, Khuzestan, jube in Karkheh River drainage (31º42'N, 48º33'E); CMNFI 1979-0363, 1, 25.8 mm standard length, Khuzestan, Karkheh River (31º52'N, 48º20'E); CMNFI 1979-0364, 2, 41.0-53.5 mm standard length, Khuzestan, river at Abdolkhan (31º52'30"N, 48º20'30"E); CMNFI 1979-0365, 24, 24.2-38.3 mm standard length, Khuzestan, stream in Doveyrich River drainage (32º25'N, 47º36'30"E); CMNFI 1979-0366, 16, 18.7-48.3 mm standard length, Khuzestan, stream 17 km west of Dehloran (32º45'30"N, 47º05'30"E); CMNFI 1979-0367, 2, 24.1-24.2 mm standard length, Khuzestan, Meymeh River 11 km north of Dehloran (32º44'30"N, 47º09'30"E) CMNFI 1979-0368, 12, 21.0-31.1 mm standard length, Khuzestan, Karkheh River (32º24'30"N, 48º09'E); CMNFI 1979-0371, 1, 24.5 mm standard length, Khuzestan, stream in Karkheh River drainage (32º05'N, 48º19'E); CMNFI 1979-0373, 12, 23.1-52.5 mm standard length, Khuzestan, Bala River north of Andimeshk (32º35'N, 48º17'E); CMNFI 1979-0374, 46, 23.3-60.2 mm standard length, Khuzestan, stream tributary to Bala River (32º40'N, 48º15'E); CMNFI 1979-0376, 9, 17.4-47.6 mm standard length, Khuzestan, river tributary to Karkheh River (32º48'30"N, 48º04'30"E); CMNFI 1979-0378, 10, 19.4-33.8 mm standard length, Khuzestan, stream tributary to Karkheh River (ca. 32º48'N, ca. 48º04'E); CMNFI 1979-0379, 11, 19.8-34.8 mm standard length, Khuzestan, Dez River (32º12'N, 48º27'E); CMNFI 1979-

0380, 5, 33.1-42.8 mm standard length, Khuzestan, stream tributary to Dez River (ca. 32º10'N, ca. 48º35'E); CMNFI 1979-0381, 28, 18.7-56.4 mm standard length, Khuzestan, stream west of Shushtar (ca. 32º10'N, ca. 48º35'E); CMNFI 1979-0382, 67, 26.7-111.3 mm standard length, Khuzestan, Karun River at Shushtar (32º03'N, 48º51'E); CMNFI 1979-0383, 1, 40.2 mm standard length, Khuzestan, stream in Ab-e Shur drainage (31º59'30"N, 49º06'E); CMNFI 1979-0384, 30, 86.3-152.2 mm standard length, Khuzestan, river in Ab-e Shur drainage (32º00'N, 49º07'E); CMNFI 1979-0386, 4, 22.9-46.1 mm standard length, Khuzestan, stream 21 km from Haft Gel (ca. 31º34'N, ca. 49º23'E); CMNFI 1979-0387, 6, 45.2-68.5 mm standard length, Khuzestan, stream 12 km from Haft Gel, Jarrahi River drainage (31º25'N, 49º38'E); CMNFI 1979-0388, 2, 29.1-33.7 mm standard length, Khuzestan, Zard River 21 km north of Ramhormoz (31º19'N, 49º44'E); CMNFI 1979-0390B, 23, 36.2-156.2 mm standard length, Khuzestan, stream tributary to Zard River (31º29'N, 49º54'30"E); CMNFI 1979-0391, 1, 154.5 mm standard length, Khuzestan, stream in Marun River drainage (31º28'N, 49º51'E); CMNFI 1979-0392, 5, 46.4-63.3 mm standard length, Khuzestan, Zard River (ca. 31º32'N, ca. 49º48'E); CMNFI 1979-0393, 2, 96.9-116.6 mm standard length, Khuzestan, Jarrahi River drainage (31º18'N, 49º37'E); CMNFI 1979-0394, 1, 130.2 mm standard length, Khuzestan, stream in Marun River drainage (31º01'N, 49º45'E); CMNFI 1979-0395, 4, 24.3-63.7 mm standard length, Khuzestan, stream in Marun River drainage (ca. 30º57'N, ca. 49º51'E); CMNFI 1991-0154, 1, 109.9 mm standard length, Khuzestan, Hawr al Azim (ca. 31º45'N, ca. 47º55'E); CMNFI 1993-0128, 1, 110.7 mm standard length, Kermanshah, Sarab-e Sabz ‘Ali Khan (34º25'N, 46º32'E); CMNFI 1993-0149, 1, 121.7 mm standard length, Khuzestan, Karun River (no other locality data); CMNFI 1995-0009A, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 1995-0010, not kept, Khuzestan, A`la River, 2 km above Pol-e Tighen (31°23.5'N 49°54'E); CMNFI 2007-0111, 6, 24.7-173.8 mm standard length, Kermanshah, Alvand River near Sar-e Pol-e Zahab (ca. 34º36'N, ca. 45º56'E); CMNFI 2007-0112, 6, 46.5-118.8 mm standard length, Kermanshah, Kerend River basin near Shahabad-e Gharb (ca. 34º06'N, ca. 46º30'E; CMNFI 2007-0113, 1, 122.1 mm standard length, Kermanshah, Razavar (= Raz Avar) River, Qareh Su tributary (ca. 34º25'N, ca. 47º01'E); CMNFI 2007-0115, 6, 59.7-154.8 mm standard length, Kermanshah, Qareh Su basin (ca. 34º34'N, ca. 46º47'E); CMNFI 2007-0116, 12, 71.6-93.0 mm standard length, Kermanshah, Gamasiab River basin west of Sahneh (ca. 34º28'N, ca. 47º36'E); CMNFI 2007-0117, 1, 142.2 mm standard length, Kermanshah, Gamasiab River basin near Sahneh (ca. 34º24'N, ca. 47º40'E); CMNFI 2008-0102, 3, 117.5-159.9 mm standard length, Kermanshah, sarabs near Kermanshah (no other locality data); CMNFI 2008-0120, 14, 17.3-132.5 mm standard length, Khuzestan, Zard Rud at Rud Zard (31º22'N, 49º43'E); CMNFI 2008-0121, not kept, Khuzestan, Zard Rud at Bagh-e Malek (31º32'N, 49º55'E); CMNFI 2008-0132, 1, 152.2 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); CMNFI 2008-0151, 1, 111.9 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); CMNFI 2008-0160, not kept, Khuzestan, Avan Abbas River at Bagh-e Malek (31º31'16"N, 49º52'32"E); CMNFI 2008-0161, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 2008-0163, not kept, Khuzestan, Marun River at Chahar Asiab (30º40'28"N, 50º09'34"E); CMNFI 2008-0165, not kept, Khuzestan, Dez River near Shush (32º14'40"N, 48º20'07"E); CMNFI 2008-0167, not kept, Khuzestan, stream above Diuni Darreh (32º37'42"N, 48º41'40"E); CMNFI 2008-0171, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'20"N, 49º52'44"E); CMNFI 2008-0173, not kept, Khuzestan, Ab-e Shur drainage (31º53'N, 49º41'E); CMNFI 2008-0179, not kept, Khuzestan, Marun River at Tang-e Khitab

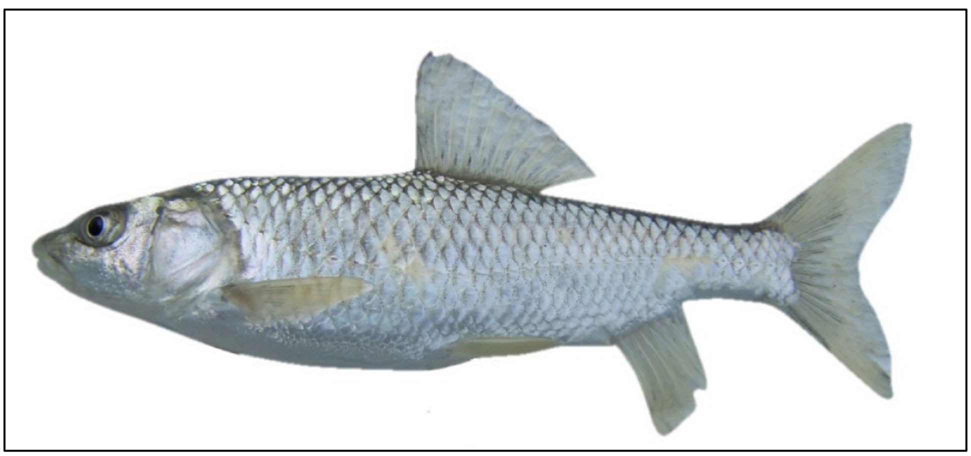
(30º40'12''N, 50º19'38''E); CMNFI 2008-0182, 1, 80.6 mm standard length, Chahar Mahall and Bakhtiari, Ab-e Bazoft Sofla (31º38'06''N, 50º28'30''E); BM(NH) 1980.8.28:1, 1, 90.3 mm standard length, Khuzestan, Dezful (32º23'N, 48º24'E).

Comparative material:- CMNFI 1980-0811, 2, 82.6-112.4 mm, Turkey, Akziyaret Deresi, Tigris River system (no other locality data); BM(NH) 1931.12.21:1-2, 2, 69.5-78.5 mm standard length, Iraq, Mosul (36º20'N, 43º08'E); BM(NH) 1974.2.22:1184, 1, 130.2 mm standard length, Iraq, Sulaymaniyah (ca. 35º34'N, ca. 45º26'E); BM(NH) 1974.2.22:1196, 1, 53.0 mm standard length, Iraq, Hawiya Canal, Lesser Zab (no other locality data); BM(NH) 1974.2.22:1214-1255 (in part), Iraq, Khalis (33º49'N, 44º32'E).

## ***Cyprinion milesi***
(Day, 1880)



*Cyprinion milesi*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Cyprinion milesi*, Baluchestan, Sarbaz River, after Jouladeh-Roudbar *et al*. (2020).

*Cyprinion milesi*, head, BM(NH) 1883.8.2:2-3,
Baluchestan, Sib near Dizak, Brian W. Coad.

**Common names**. Butak-e Hormuz (= Hormuz butak, meaning of butak unknown), lutak sharghi.

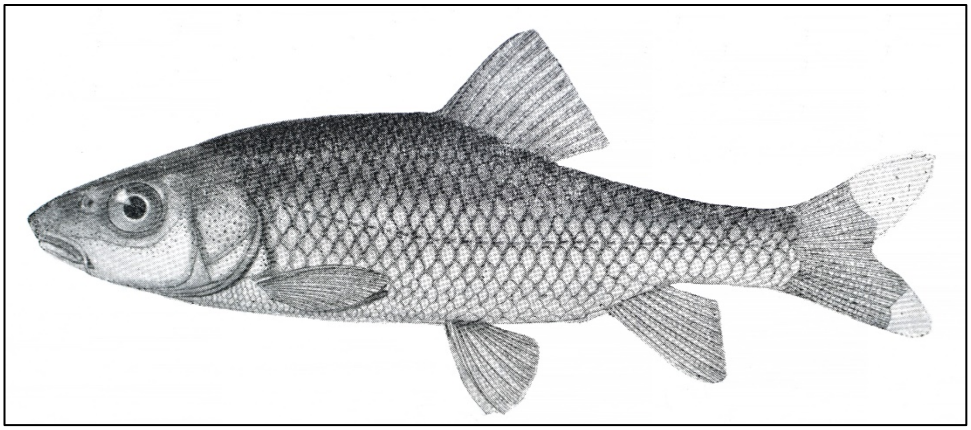
[Sabzug in Pakistan; bighead lotak (Nasri *et al*., 2016b); eastern lotak].

**Systematics.** *Barbus milesi* was described from "a spring at Tràl", Pakistan.

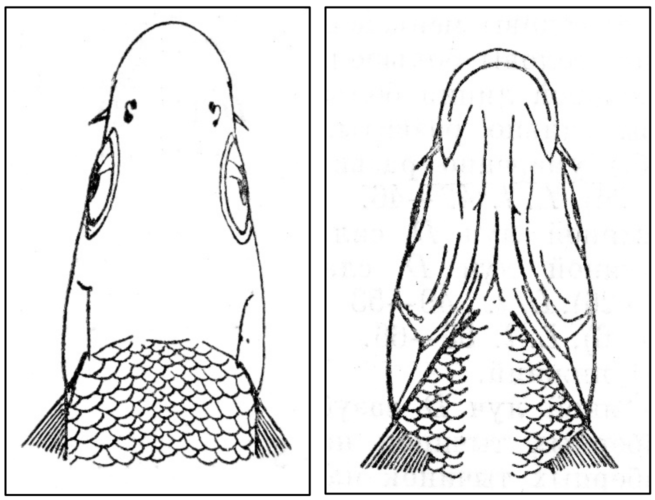
Berg (1949), Mirza (1969), Mirza *et al*. (1991) and Howes (1982) recognised this species as valid. If so, synonyms according to Berg (1949), would be *Barbus bampurensis* Nikol'skii, 1899 (given as 1900 but possibly 1899 in the *Catalog of Fishes*, downloaded 23 May 2018) described from "Flum. Bampur", *Scaphiodon daukesi* Zugmayer, 1912 from "Irrigation channels and pools near Panjgur, Baluchistan, Pakistan", and *Barbus baschakirdi* Holly, 1929 from "Ein Bach bei Guadjik am Wege von Sarzeh in Biabun nach Darpahan in den Bergen von Baschakird, Südostpersien" (= a brook at Guadjik on the way from Sarzeh in Biabun to Darpahan in the Baschakird Mountains, southeast Persia; Sarzeh is at 26°26'N, 57°16'E and Dar Pahn is at 26°37'N, 57°34'E).

A specimen in the Naturhistorisches Museum Wien under NMW 52736, 34.4 mm standard length, is listed as a syntype under the name *Cirrhina milesi* but its locality is Gwadur, Hubb River and the type status may be an error.

Five syntypes of *Barbus bampurensis*, 32.0-64.8 mm standard length, are in the Zoological Institute, St. Petersburg (ZISP 11715) from "Flum. Bampur, 15-23.VII.1898, Zarudnyi". The jar label gives a date of 15-19.VII.1898.



*Barbus bampurensis*, 6.9 or 7.9 cm total length, ZISP 11715, syntype, Baluchestan, Bampur River, after Berg (1949).



*Barbus bampurensis*, dorsal and ventral heads, as above.

The holotype of *Barbus baschakirdi*, 52.2 mm standard length, is in the Naturhistorisches Museum Wien under NMW 13798 and a cotype (syntype) of *Scaphiodon daukesi*, 102.8 mm standard length, is under NMW 19784.

*Scaphiodon daukesi* types in Munich were destroyed in World War II but one syntype is in the Naturhistorisches Museum Wien under NMW 19784, and two syntypes are in the Zoological Survey of India, Calcutta under ZSI F8028/1 and 8032/1 (Menon and Yazdani, 1968; Eschmeyer *et al*., 1996; Neumann, 2006).


*Scaphiodon daukesi*, NMW 19784, Brian W. Coad.

Much of my material from southeastern Iran was assigned by me to *C. watsoni*. Many samples comprise small fish and the change in mouth shape with age, or other distinctive characters, have not been thoroughly investigated in *C. milesi*. Specimens that resemble *C. milesi* (lacking a shallowly arched or sector mouth with a horny edge but having an oblique u-shaped mouth) are found at the same sample localities as typical *C. watsoni*. The mouth structure of the putative *C. milesi* resembles that of juvenile *C. watsoni*, possibly retained in the adult (paedomorphosis). A principal components analysis did not separate these two forms when the mouth characters are not included in the analysis. Nasri (2015), however, found a high genetic distance between this species and other *Cyprinion* species in Iran and Nasri *et al*. (2018) found a clear distinction from other *Cyprinion* species by having the largest head height/body depth, the lowest body depth/standard length, the lowest dorsal fin base length/standard length, the lowest pectoral fin length/standard length, and the lowest dorsal fin height/standard length ratios. Sexual dimorphism in this genus was said to be absent and sexes were not separated in the analyses.

**Key characters.** The mouth is characteristically oblique, longer in lateral view than *C. watsoni*.

**Morphology.** The body is rounded, somewhat compressed and moderately deep, being deepest in front of the dorsal fin. A nuchal hump may be present. The predorsal profile is straight or slightly convex. The caudal peduncle is compressed and shallow to moderately deep. The head is more massive in relation to the body than for similar size *C. watsoni/kirmanense* specimens. The snout is rounded and the eye centre is anterior to the mid-point of the head or the rear of the eye lies at the beginning of the anterior half of the head. The oblique mouth reaches back to the anterior eye margin in small fish and to the rear of the nostril in larger fish. The upper lip is thick and the lower lip is thin. The barbel is quite stubby at the base but tapers rapidly to the tip in larger fish and extends back between the nostril and the eye. The dorsal fin spine is strong and serrated, with large teeth in small fish, weaker in size and teeth in large fish. The dorsal fin margin is straight and the dorsal fin origin lies anterior to the level of the pelvic fin origin. The depressed dorsal fin reaches back to the level of the middle of than anal fin. The caudal fin is moderately forked with rounded lobes. The anal fin is rounded and does not extend back to the caudal fin base. The pelvic fin is rounded and almost extends back to the anal fin origin or falls short. The pectoral fin is slightly emarginate and then becomes rounded, and does not extend back to the pelvic fin origin.

Dorsal fin with 3 unbranched and 9-13 branched rays (Nasri *et al*. (2018) give 9(59) or 10(41)), anal fin with 2 unbranched and 6-7 branched rays (Nasri *et al*. (2018) give 6(69) or 7(31)), pectoral fin branched rays 13-16, and pelvic fin branched rays 6-8. Lateral line scales 34-39 (Nasri *et al*. (2018) give 37(28) or 38(72)). The scaleless groove before the dorsal fin is weakly expressed. Scales are present on the belly of large fish, almost absent on small fish. Upper flank scales may be regularly or irregularly arranged. A pelvic axillary scale is present. Scales have few to no anterior radii, numerous posterior radii, numerous fine circuli, a subcentral anterior focus, and an anterior scale margin indented above and below the mid-line. Total gill rakers number 11-16 and total vertebrae 37-39.

The type series of *Barbus bampurensis* (= *C. milesi*) has dorsal fin branched rays 10(4) or 11(1), anal fin branched rays 7(5), pectoral fin branched rays 14(1) or 15(3) (one unclear), pelvic fin branched rays 7(1) or 8(4), lateral line scales 34(1), 36(1) and 37(3), and total gill rakers 11(3) or 12 (2). Two fish from Sib and one fish from the Dozdan River (see **Sources** below) had dorsal fin branched rays 9(1), 10(1) or 11(1), anal fin branched rays 7(3), pectoral fin branched rays 15(2) or 17(1), pelvic fin branched rays 6(1), 7(1) or 8(1), lateral line scales 35(1) or 37(2), pharyngeal teeth 4,3,2 on the left side, total gill rakers 13(2) or 14(1), and total vertebrae 38(1) or 39(1). Gill rakers are short and widely spaced in the middle of the lower arch, not reaching the adjacent one when appressed. Pharyngeal teeth have a slight hook on the anteriormost tooth, with the rest in the main row with scooped-out crowns. Nasri *et al*. (2018) gave 37(44), 38(44) or 39(12) total vertebrae.

Nasri *et al*. (2016a) differentiated this species from others in Iran including *C. watsoni* by it having the longest and narrowest neurocranium. Nasri *et al*. (2016b) described the osteology of this species and compared and differentiated it to that of *C. kais* and *C. macrostomus* but not *C. watsoni* also found in southeast Iran.

**Sexual dimorphism.** Tubercles line the anal fin rays and are apparent on the snout in males below nostril level.

**Colour.** The body is copper-brown on the back and upper flank fading to a pinkish belly. Scales are narrowly outlined by pigment. Fins are grey to pink and the lateral line has a bright orange streak along it, not always present. Fin membranes may be pigmented while rays are less so. The pectoral fin has some scattered pigmentation while the pelvic and anal fins can be immaculate. The central ray and membranes of the caudal fin are darker than the rest of the fin. The preopercle has orange-golden spots as does the base of the pectoral fins. There is a dark blotch at the base of the caudal fin. The caudal fin base bears a spot in small specimens and there are some much smaller, irregular spots on the caudal peduncle. The peritoneum is brown to black.

**Size.** Attains about 19.0 cm.

**Distribution.** In Iran, this species is found in the Hamun-e Mashkid, Hamun-e Jaz Murian, Hormuz and Makran basins. In the Hamun-e Mashkid basin in the Mashkid River at Sib; Hamun-e Jaz Murian basin in the Bampur River (Berg, 1949; Jouladeh-Roudbar *et al*., 2015); in the Hormuz basin in the Dozdan River (Jouladeh-Roudbar *et al*., 2015); and in the Makran basin in the Minab and Sarbaz rivers and at Guadjik in the Baschakird Mountains (Holly, 1929a; Saadati, 1977; Jouladeh-Roudbar *et al*., 2015; Nasri *et al*., 2016, 2018, 2019). Also in the Mashkid River basin in Pakistan and in Pakistani rivers draining to the Indian Ocean. Jouladeh-Roudbar *et al*. (2020) maintained that specimens reported from the Hamun-e Mashkid, Hamun-e Jaz Murian and Hormuz basins were probably misidentifications (but see synonyms above).

**Zoogeography.** Zoogeographical comments are under the genus above.

**Habitat.** This species is found in rivers, streams and springs.

**Age and growth.** Unknown.

**Food.** Unknown but Nasri *et al*. (2019) attributed the large head and wide, oblique mouth to a trophic adaptation to carnivory.

**Reproduction.** Unknown.

**Parasites and predators.** None reported from Iran.

**Economic importance.** None.

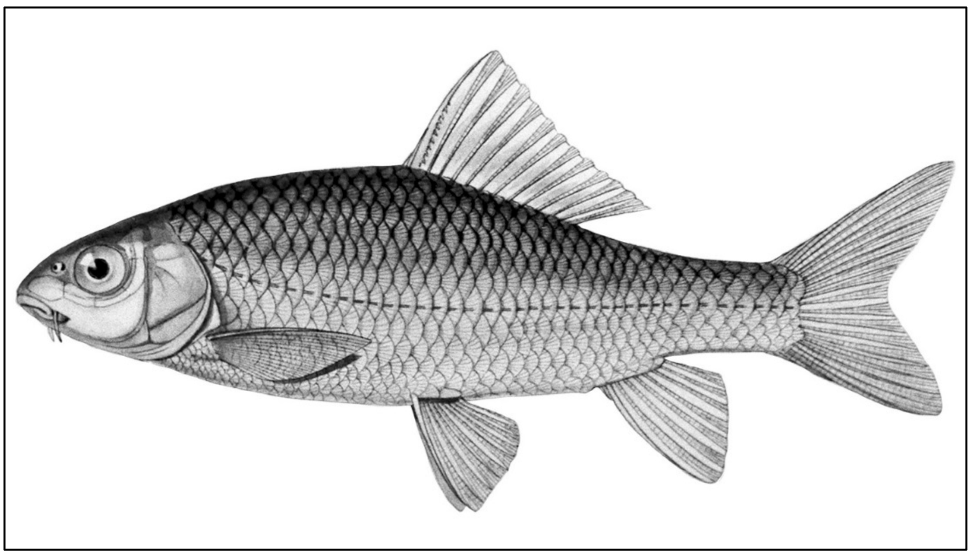
**Experimental studies.** None.

**Conservation.** The distribution, abundance and biology of this species in Iran is poorly known and an assessment for conservation status cannot be given. Jouladeh-Roudbar *et al*. (2020) listed this species as Data Deficient.

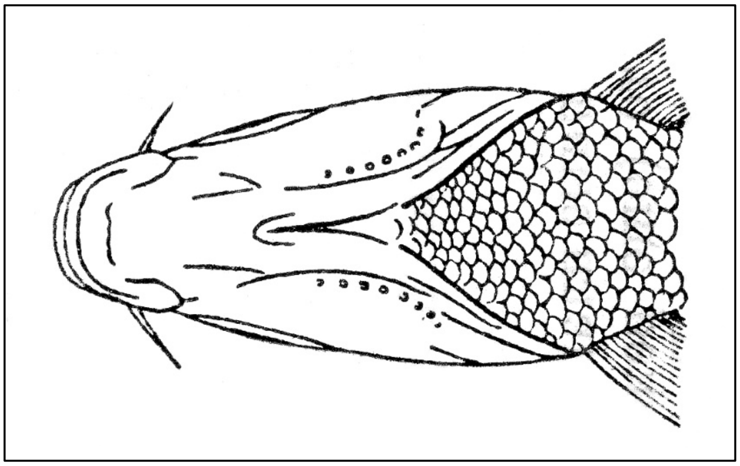
**Sources.** Type material:- *Barbus bampurensis* (ZISP 11715), *Barbus baschakirdi* (NMW 13798) and *Scaphiodon daukesi* (NMW 19784).

Iranian material:- CMNFI 2008-0141, 1, 162.4 mm standard length, Hormozgan, Dozdan River at Rudan (27º26'N, 57º10'E); BM(NH)1883.8.2:2-3, 2, 72.2-130.9 mm standard length, Baluchestan, Sib near Dizak (27º15'N, 62º05'E).

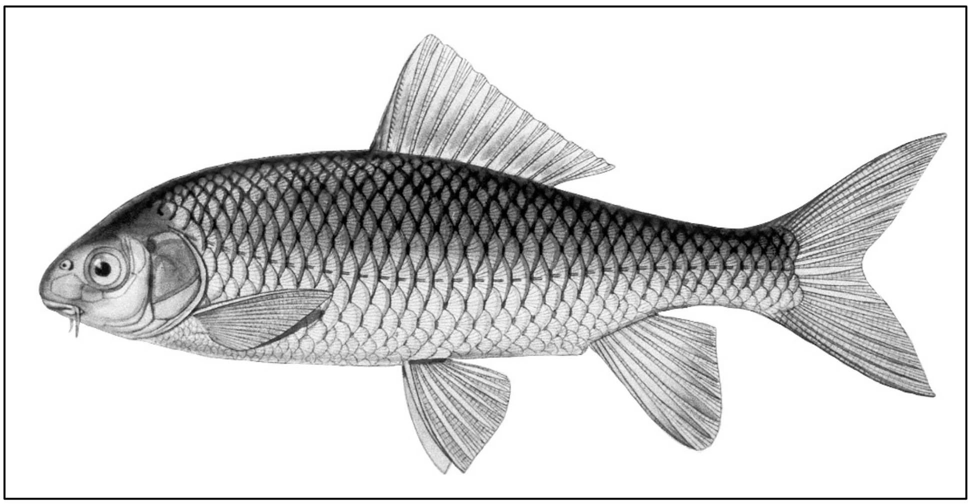
***Cyprinion tenuiradius***
Heckel, 1847



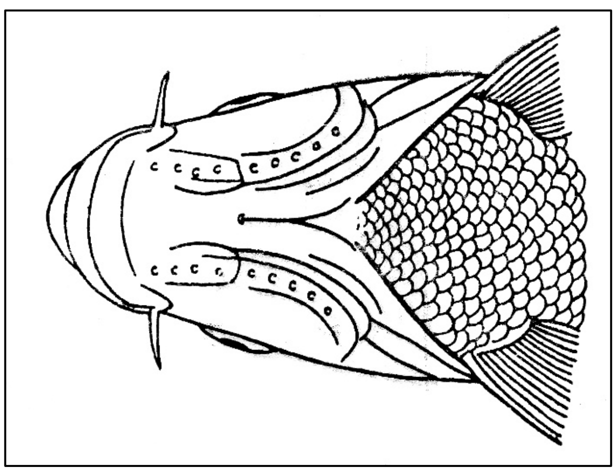
*Cyprinion tenuiradius*, 8.2 cm total length, Khuzestan (= Arabistan), Al Khorshir 10 km from Qaleh-ye Tol, after Berg (1949).



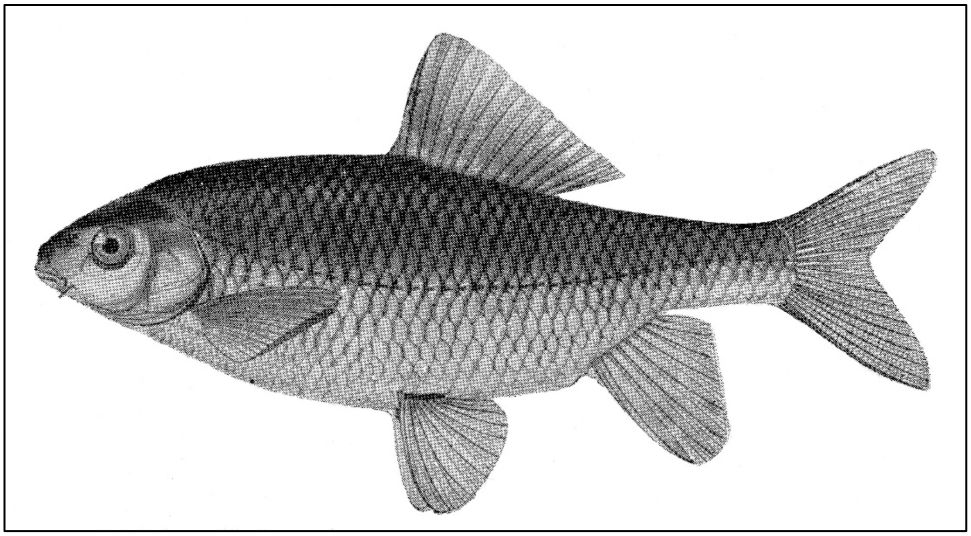
*Cyprinion tenuiradius*, ventral head, as above.



*Cyprinion tenuiradius*, 14.5 cm total length, ZISP 24051, Khuzestan, Kuhlihan between Shushtar and Qaleh-ye Tol, after Berg (1949).



*Cyprinion tenuiradius*, ventral head,
ZISP 24048, Khuzestan,
Rogan Spring between Qaleh-ye Tol and
Dzhoru (= Dehora), Karun River basin,
after Berg (1949).



*Cyprinion tenuiradius* morpha *elata*, 13.5 cm total length, ZISP 24051,
Khuzestan, Kuhlihan between Shushtar and Qaleh-ye Tol, Karun River basin,
after Berg (1949).

Note that the three above line drawings from Berg (1949) may be *C. macrostomus* based on distribution although spine development is weak. Also, the drawing of ZISP 24051 just above seems to be repeated in Berg (1949) as a drawing under ZISP 24058 (*C. tenuiradius*, 14.6 cm, Arabistan) but the catalogue number and length of the latter do not agree with the text.

*Cyprinion tenuiradius*, Fars, upper Mond River, Hamid Reza Esmaeili.

**Common names.** Botak, butak-e Fars, Qarah Aqhaj botak or butak (meaning of botak and butak unknown) (Gholamifard *et al*., 2012; Tabatabai *et al*., 2020), lotak Qarah Aqhaj (Jouladeh-Roudbar *et al*. (2020).

[Araxes kingfish (Fricke *et al*., 2007), and see also under *C. macrostomus*; Qarah Aqaj botak or lotak].

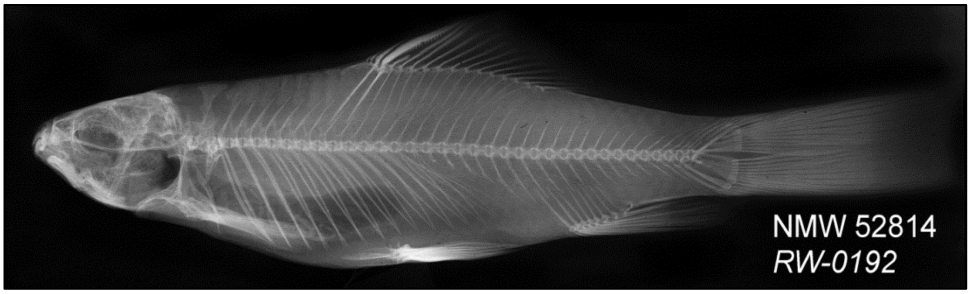
**Systematics.** The type locality is the “Kara-Agatsch als aus dem Araxes” (= Qarah Aqaj River and the Kor River, Fars). The *Catalog of Fishes* (downloaded 12 November 2019) listed the “Aras, Tigris and Persis River systems: Turkey, Irak and Iran”. The classical Araxes, modern Kor River, was confused with the Aras River of the Caspian Sea basin of eastern Turkey which also forms part of the northwestern border of Iran. *Cyprinion* species do not occur in the Caspian Sea basin. This species does not seem to occur in the Kor River basin either and so there may be some labelling error in the type material. Esmaeili *et al*. (2018) and

Jouladeh-Roudbar *et al*. (2020), recent checklists of Iranian fishes, do not list it from the Kor River basin. Banarescu and Herzig-Straschil (1995) listed types as from the Qarah Aqaj. It may occur in southern Iraq but see comments below.

Sometimes spelt *tenuiradiatus* (e.g., in Rainboth (1981) but this is incorrect). Syntypes (now lectotype and paralectotypes) of *Cyprinion tenuiradius* are in the Naturhistorisches Museum Wien according to Kähsbauer (1964) under NMW 52808 (1 specimen, 116.7 mm standard length), 52809 (2, 52.3-58.0 mm standard length) (but listed as only one specimen in the Ichthyology Type Database, NMW, downloaded 9 July 2016), NMW 52811 (4, 42.7-47.4 mm standard length), NMW 52815 (1, 77.0 mm standard length) and NMW 52816 (2, 75.5-80.8, although Kähsbauer (1964) and the Ichthyology Type Database, NMW (downloaded 9 July 2016) listed only one while Banarescu and Herzig-Straschil (1995) listed two as also found by me). Other material marked as syntypes from the “Kara-Agatsch. Th. Kotschy” includes NMW 52810 (2, 103.7-110.0 mm standard length), NMW 52812 (2, 103.5-104.8 mm standard length), NMW 52813 (2, 97.7-103.1 mm standard length), NMW 52814 (1, 114.9 mm standard length), and 52817 (1, not examined). The catalogue in Vienna listed eight specimens in one column and 26 in the adjacent column. Eschmeyer *et al*. (1996) added two fish from the Araxes River, formerly in NMW, now at the Rijksmuseum van Natuurlijke Historie, Leiden (now Nederlands Centrum voor Biodiversiteit Naturalis) under RMNH 2486 (and these are presumably mislabeled specimens). The lectotype as selected by F. Krupp in 1984 is NMW 52814 and is published by Banarescu and Herzig-Straschil (1995) with NMW 52808, 52809, 52810, 52811, 52812, 52813, 52815, 52816 and 52817 as paralectotypes.

Berg (1949) figured a *Cyprinion tenuiradius* morpha *elata* (ZISP 24051, see above) but this is presumably in reference simply to the body form (*elata* is Latin for elevated or high, in this sense meaning deep-bodied) and not a taxonomic usage. It is not mentioned in the *Catalog of Fishes* (downloaded 10 September 2020).


*Cyprinion tenuiradius*, lectotype, NMW 52814, Naturhistorisches Museum, Wien.

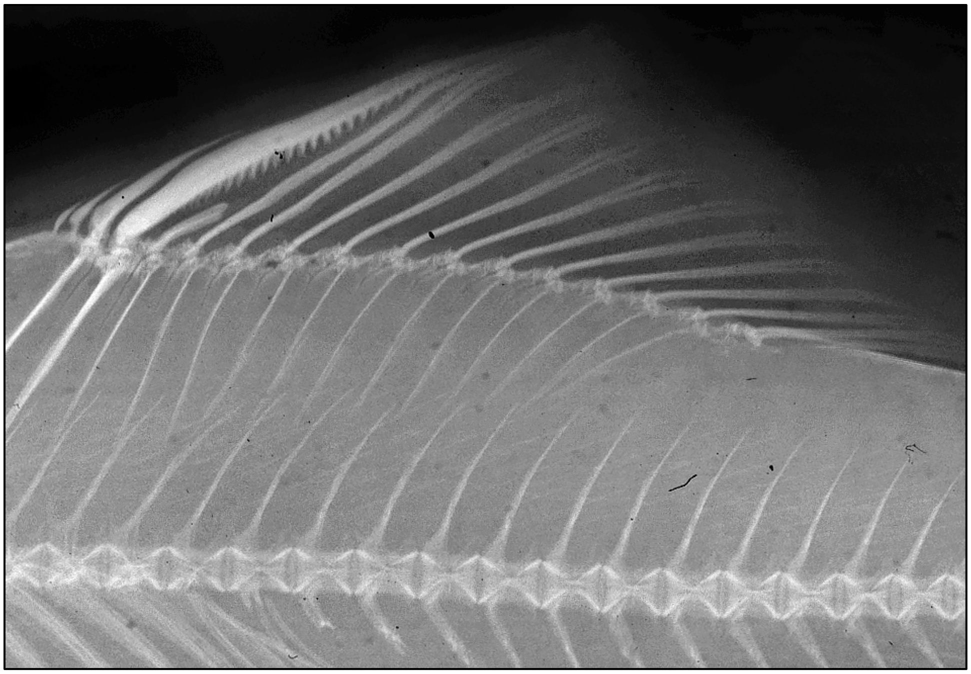



*Cyprinion tenuiradius*, lectotype, NMW 52814, Naturhistorisches Museum, Wien.

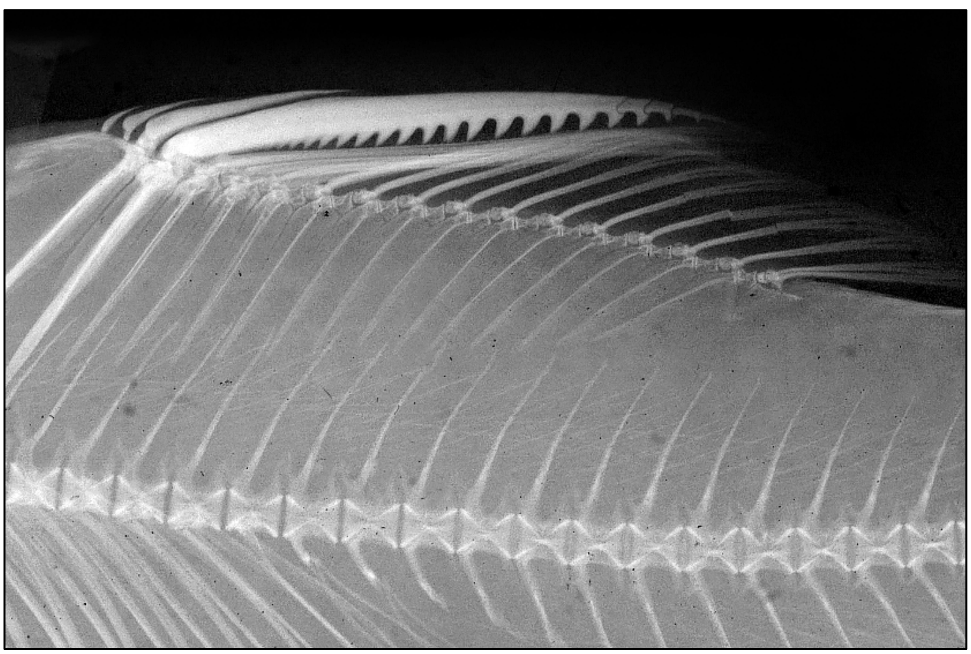
Karaman (1971) assigned this taxon as a subspecies of *Cyprinion macrostomus* and Bianco and Banarescu (1982) suggested it may be a subspecies in a polytypic species. Berg (1949) recorded it from the Tigris River where it may be sympatric with *C. macrostomus*. He considered it to be close to that species, perhaps its southeastern subspecies. Howes (1982) considered *tenuiradius* to be a variant of *C. macrostomus*.

Heckel (1847b) distinguished this species from *C. macrostomus* by a lower scale count (35-36 as opposed to 42; Berg (1949) gave 35-38 compared to 37-43; Krupp (1985c) gave 34-38 compared to 39-43; Banarescu and Herzig-Straschil (1995) gave 36-38, rarely 35 or 39 compared to 41-44, rarely 40 or 45), a slenderer body, and a much thinner dorsal spine which is soft in its distal third. The mouth is arched and there is some lower lip development at the mouth corner as in *C. kais* (see illustrations in Krupp (1985c)). In addition, Berg (1949) gave a branched dorsal fin ray count of 12-13 in *C. tenuiradius*, 13-15 in *C. macrostomus*, although Banarescu and Herzig-Straschil (1995) gave (12)13-15 for *C. tenuiradius* from the type locality of Kara-Agasch (*sic*). My counts for *C. macrostomus* types (NMW 52805, 52806, and including *C. neglectus* types, NMW 52807) and *C. tenuiradius* types (NMW 52808, 52810, 52812, 52813, 52814) for dorsal fin branched rays are 13(2), 14(6), 15(5) or 16(3) and 12(1), 13(-), 14(6) or 15(1) respectively. Krupp (1985c) stated that *tenuiradius* has a smaller number of scale radii than *macrostomus*, radii are divergent and the posterior scale margin is curved. However, data for specimens examined by me show overlaps in meristic characters; although means may differ, individual fish would be difficult to distinguish on counts alone.

The question then arises as to whether *tenuiradius* is distinct from *macrostomus* or merely a variant of a wide-ranging, variable species. The only absolute character is supposedly a weaker dorsal fin spine with less-developed or finer teeth (denticles) that do not extend as far along the spine. This is the case based on examination of type material by me. However, note that the spine tip is thin and weakly denticulate in some *C. macrostomus* but this tip is much shorter than in *C. tenuiradius*. There is variation in spine strength and denticulation between individuals within and between the two species.



*Cyprinion tenuiradius*, lectotype, NMW 52814, dorsal fin,
Naturhistorisches Museum, Wien.



*Cyprinion macrostomus*, paralectotype, NMW 52805, dorsal fin,
Naturhistorisches Museum, Wien.

Other, meristic characters overlap and minor variations in body form are difficult to quantify given a wide range of habitats (lowland rivers and marshes versus highland streams) which may affect shape. The species *tenuiradius* is retained here as distinct but would benefit from further analyses using new characters, if available, and from molecular data. Nasri *et al*. (2018) in their morphometric and meristic study of Iranian *Cyprinion* species could not distinguish *C*.

*tenuiradius* from *C. macrostomus* except for the dorsal fin spine development (but see below). Nasri *et al*. (2019) also noted that the two species are difficult to distinguish morphometrically. Identification here is based on locality rather than any morphology, while recognising this is unsatisfactory. Some Tigris River basin fish may be *tenuiradius* and some Persis basin fish may be *macrostomus* (see Berg (1949) for example and **Distribution** below.

**Key characters.** Distribution and a weak spine distinguish this taxon. The dorsal fin spine in *macrostomus* has teeth extending further along the spine, and teeth are more well-developed even near the tip. Spine teeth in *tenuiradius* are more graded in size as they near the tip and are finer than in *macrostomus*. However, the spine character does not hold for all specimens examined here as there are developmental differences (age and size) and the character overlaps with *C. macrostomus*.

**Morphology.** The body is rounded, somewhat compressed and relatively deep. The deepest part of the body is at the dorsal fin origin. The predorsal profile is slightly to markedly convex and the head falls sharply to the rounded snout. There is a naked dorsal keel in front of the dorsal fin, although the area behind the occiput may be scaled and the groove begins nearer the dorsal fin. There is a groove across the snout in front of the nostrils. The mouth is transverse to more or less curved. Lips are thin, and moderate at the upper corner. The barbel is thin and extends back to the anterior or middle of the eye. The dorsal fin spine is weak to moderate and serrated only half way or two-thirds of its length (see figure above). The dorsal fin margin is concave and the dorsal fin origin lies just anterior to the level of the pelvic fin origin. The depressed dorsal fin extends back level with the middle to the end of the anal fin. The caudal fin is deeply forked with pointed tips. The anal fin margin is rounded to straight and the fin may almost reach back to the caudal fin base or fall well short. The pelvic is rounded overall but may have a straight margin and the fin does not reach back to the anal fin origin. The pectoral fin has a falcate to straight margin and does not extend back to the pelvic fin origin.

Dorsal fin with 4 unbranched and 11-15 branched rays (Berg (1949) has 12-13). The anal fin has 3 unbranched and 6-8 branched rays, usually 7. In 199 Iranian fish, 96.5% have 7 anal fin rays with the rest having 6 rays and 1, presumably anomalous fish, with 9 rays. Pectoral fin branched rays 10-18 (Nasri *et al*. (2018) give 10(19), 11(36), 12(42) or 13(3)), and pelvic fin branched rays 6-9, usually 7-8. Lateral line scales 32-39. Scales on the belly may be small and skin covered. There is a pelvic axillary scale. Scales are squarish. The dorsal and ventral scale margins are straight to slightly rounded, the posterior margin is a rounded but a shallow arc, the anterior margin is indented on each side of a large central projection, and the dorsal and ventral anterior corners are rounded but abrupt. The focus is subcentral anterior, there are numerous very fine circuli, and there are numerous posterior radii. Total gill rakers number 10-21 and extend just past the adjacent raker when appressed. Total vertebrae number 37-40. The chromosome number is 2n = 50, comprising 13 metacentric, five sub-metacentric and seven sub-telocentric chromosomes pairs. Arm number is NF = 86 (Esmaeili and Piravar, 2006).

Meristic values for fish from Persian Gulf drainages of Fars, Bushehr and Hormozgan provinces including the Lake Maharlu endorheic basin are:- dorsal fin branched rays 11(4), 12(51), 13(175), 14(74) or 15(9) (mean = 13.1, S.D. = 0.746), pectoral fin branched rays 13(3), 14(38), 15(117), 16(41), 17(2) or 18(1) (mean = 15.0, S.D. = 0.733), pelvic fin branched rays 7(23), 8(177) or 9(3) (mean = 7.9, S.D. = 0.345), total gill rakers 10(2), 11(16), 12(27), 13(24), 14(49), 15(35), 16(20), 17(14), 18(8), 19(3), 20(-) or 21(1) (many counts are based on small

specimens and may be low accordingly in comparison with Tigris River basin fishes; mean = 14.2, S.D. = 2.003), lateral line scales 32(1), 33(15), 34(28), 35(41), 36(47), 37(56), 38(13) or 39(2) (mean = 35.7, S.D. = 1.431), and total vertebrae including the lectotype 36(1), 37(12), 38(24) or 39(4). The lectotype, NMW 52814, above has 38 vertebrae.

**Sexual dimorphism.** Fish from the Shapur River (CMNFI 1979-0026, 15 June 1974, 69.3 mm standard length) have tubercles on the snout in front of the eyes, below the nostril level with smaller scattered tubercles on the sides of the head. Tubercles on the anal fin are large, following the rays in a single row. Scales on the flank near the anal fin and on the caudal peduncle bear small tubercles. The dorsal, caudal, pectoral and pelvic fins have very small tubercles. Fish from Pol-e Gaz in the Lake Maharlu basin (CMNFI 1979-0504, 30 May 1978, 95.7-103.3 mm standard length) have moderately large, concentrated tubercles from under the eye around the snout below the nostril level and scattered on the operculum and lower cheek. Very fine tubercles are present on top of the head. Scales on the posterior body back from above the pelvic fin level have a few, irregularly scattered tubercles. The dorsal and caudal fins have small tubercles, mostly in a single row but with some following the branching rays. The anal fin has large tubercles, often in a single row on the rays, sometimes branching with the rays. The pectoral and pelvic fins lack tubercles except for the occasional one.

**Colour.** Overall colour is yellowish-white to silvery or olive-green with a light grey back. Scale bases on the flank above the lateral line are brown and upper flank scales may be outlined. The flank immediately behind the operculum may be orange with orange spots extending along the lateral line as far as the anal fin level. Some sparse orange spotting also appears on the lower anterior flank and the operculum. The pectoral and pelvic fins have an orange-yellow spot at their base. Fins are mostly clear to greyish with some darker pigment on the rays. In preserved fish the dorsal fin membranes are darkly pigmented while the rays are mostly clear. There is no pattern to the dorsal fin pigmentation. Caudal fin rays and membranes are pigmented but less than the membranes in the dorsal fin. Anal fin membranes are darker than the rays, and are darker distally. The pelvic fin has very little pigmentation and the pectoral fin rays and membranes are lightly speckled. Young fish may have a few vague and irregular flank blotches, a caudal spot, a spot at the anterior dorsal fin base and blotches under the dorsal fin on the upper flank.

**Size.** Reaches 19.5 cm total length (Esmaeili *et al*., 2014).

**Distribution.** This species is found in various qanats, springs and streams in the Lake Maharlu and Persis basins (see **Sources** below). In the Lake Maharlu basin at, for example, Pol-e Berengie; and in the Persis basin in the Abarak, Ahram, Baghan, Dalaki, Daralmizan, Dehram, Fahlian, Faryab, Firuzabad, Helleh, Kheyrabad, Mond, Qarah Aqaj, Rudbal (= Rudbar), Shapur, Shirin, Shiv, Shur and Zohreh rivers, and in Lake Parishan (Bianco and Banarescu, 1982; Izadpanahi, pers. comm., 1995; M. Rabbaniha, pers. comm., 1995; Abdoli, 2000; Teimori *et al*., 2010; Esmaeili and Gholamifard, 2012; Gholamifard *et al*., 2012, 2017; Sedaghat and Hoseini, 2012b; Zareian *et al*., 2012; Sadeghi Limanjoob *et al*., 2014; Esmaeili *et al*., 2015, 2015; Pazira *et al*., 2016; Gholamifard, 2017; Keivany and Zamani-Faradonbe, 2017a; Maramaei *et al*., 2017; Zamanpoore, 2017; Fekrandish *et al*., 2018; Golchin Manshadi *et al*., 2018; Nasri *et al*., 2018; Tabatabai *et al*., 2020).

Banaee and Naderi (2014) recorded it from the Marun River in Khuzestan but this may be a mis-identification. Material from, and including, the Zohreh River eastwards to the Mond River basin are identified here as *C. tenuiradius* as the rivers drain directly to the Persian Gulf and are therefore isolated from rivers of the Tigris River basin. Fish from the Marun River and

northward are all part of the Tigris River basin (and its confluence with the Euphrates River, the Shatt al Arab or Arvand River) and these are identified as *C. macrostomus*. This is recognized here as arbitrary and unsatisfactory and further work is needed to clarify taxon identity and distribution.

Berg (1949) recorded this species from several localities (here with amended spellings indicated by * but similar to the original), *Band-e Amir (Kor River basin - but see below), *Qarah Aqaj River (Persis basin).

Heckel's description recorded this species as from the "Araxes", the modern Kor River in Fars. However, the catalogue sheets in Vienna for the types only listed the "Kara Agatsch" (= Qarah Aqaj River) and no subsequent collections have been made of this species in the internal Kor River basin although Abdoli (2000) also mapped it from the middle to lower Kor River, possibly based on Heckel's report. Berg (1949) recorded it from the Tigris River basin, perhaps in error, and Fricke *et al*. (2007) have it in Turkey from the Aras River system of eastern Turkey (presumably a confusion of the modern Aras or Araxes River with the classical Araxes or Kor River of Fars).

**Zoogeography.** Zoogeographical comments are under the genus above.

**Habitat.** This species is found in rivers, streams, pools, rapids, backwaters, springs and qanats. Collection data included a temperature range of 9-30ºC, pH 6.0-7.0, conductivity 0.3-6.0 mS, river width 1-100 m, still to fast current, depth 2 cm to 2 m, clear and colourless or cloudy water, mud, sand, gravel, pebble, stone, boulder or bedrock bottoms, encrusting, submergent filamentous algae, gelatinous brown masses and *Sagittaria*, emergent reeds and rushes, foliose and floating vegetation, and a grassy, bushy or forested shore.

Darabi *et al*. (2021) used climatic and environmental variables as determining factors (independent variables) which included topographic, bioclimatic and soil and bedding-related variables to model habitat suitability. The results indicated the high importance of the average annual temperature variable as a determining factor in the process of habitat selection for this species. Temperatures between 17 and 28°C created the most suitable habitat. The study also showed that due to climate change, the habitat of this species will decrease slightly in 2050, while in 2080 its habitat will noticeably increase.

Habitat of *Cyprinion tenuiradius*, Fars, Mond River, Hamid Reza Esmaeili.

**Age and growth.** Esmaeili and Ebrahimi (2006) gave a significant length-weight relationship based on 40 fish measuring 5.04-13.49 cm fork length with a *b*-value of 3.063). Esmaeili *et al*. (2014) gave a *b* value for 341 fish from the Persian Gulf (Persis) basin, 3.24-19.5 cm total length, as 3.05.

Sedaghat and Hoseini (2012b) found positive allometric growth for 70 fish, 4.1-9.2 cm total length, in the Dalaki River, Bushehr with the *b* value not significantly different between sexes and $W = 0.06L^{3.1}$ for the population. Bibak *et al*. (2013c) gave length-weight relationships for fish from the Dalaki (2.8-17.7 cm total length) and Shapur (2.5-15.5 cm total length) rivers as $W = 0.015L^{3.129}$ and $W = 0.027L^{2.935}$ respectively based on 91 and 80 fish. The relationship was positively allometric for Dalaki fish and negatively allometric for Shapur fish. Zamani-Faradonbe (2017a) gave a *b* value of 2.86 for 32 Zohreh River fish, 2.7-10.8 cm total length. Maramaei *et al*. (2017) examined 610 fish, 2.5-13.0 cm total length, from the Dalaki River and found a male:female sex ratio of 1:1.19, length-weight relationships were $W = 0.0076TL^{3.15}$ for males and females, $W = 0.0076TL^{3.16}$ for the population (positively allometric). Condition factors were highest in April and July in males with the lowest value in March while for females the highest value was in July and the lowest in March. Fekrandish *et al*. (2018) examined 332 males and 358 females from the Dalaki River basin, and found a sex ratio of 1:0.92, *b* values of 2.89 for males, 2.93 for females and 2.91 for sexes combined (isometric growth), age classes were 0 to 4 years, males were 3.0-16.5 cm total length and females 3.5-17.1 cm, the von Bertalanffy growth parameters calculated using the mean total length and total weight at ages were Lt = 170.11[1-exp(-0.213(t+1.12))], Wt = 115.09 [1-exp(-.213 (t+1.12))]2.89 in males and Lt = 164.14[1-exp(-0.189(t+1.16))], Wt =117.11[1-exp(-0.189(t+1.16))]2.93 in females, males grew less rapidly than females, attainment of maximum size was slow, and instantaneous growth rate increased up to age 2 and then decreased with age in both sexes.

**Food.** Tabatabai *et al*. (2020) examined the diet of 39 fish in the Firuzabad River and found the gastrosomatic index, status, nutritional intensity, gastric emptying and relative length

of the intestine were 23.64, 1.07, 1,370 and 7.69, respectively (*sic*), indicating good nutritional intensity, good living conditions, full stomach and overeating. Dietary items were the microalgae of the genera *Navicula*, *Cymbella*, *Diatoma*, *Pinnularia*, *Gomphonema* and *Cosmarium*, and small numbers of *Cymatopleura*, *Caloneis*, *Nitzschia*, *Spirogyra* and *Pediastrum*.

**Reproduction.** Esmaeili and Gholamifard (2012) described the ultrastructure of the chorion and micropyle of the unfertilised egg and Gholamifard *et al*. (2012, 2017) gonad histology and morphology. Spawning was once a year in spring and summer (April to July) in the Rudbal (= Rudbar) River based on gonad maturation (Gholamifard *et al*., 2012, 2017).

**Parasites and predators.** Gholamifard *et al*. (2010) reported papillomatosis (skin warts) in this species. Golchin Manshadi *et al*. (2017) recorded *Allocreadium* sp., *Dactylogyrus carasobarbi*, *Gyrodactylus* sp., *Ichthyophthirius multifilis* and *Myxobolus* sp. from fish identified as *Cyprinion macrostomus*, presumably the current species, in the Shapur River, Fars. Maleki *et al*. (2018) recorded metacercariae of the trematode *Clinostomum complanatum* from fish in the Qeshlaq River basin. Golchin Manshadi *et al*. (2018) reported *Allocreadium* sp., *Bothriocephalus* sp. and *Rhabdocona* sp. from fish identified as *C. macrostomus* from the Fahlian River, Fars.

**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** The distribution, abundance and biology of this species in Iran is poorly known and an assessment for conservation status cannot be given. Jouladeh-Roudbar *et al*. (2020) listed it as Least Concern since it occurs in large numbers over its distribution range and does not seem to have been affected by drought and dam construction. Endangered in Turkey (Fricke *et al*., 2007) but does not occur there.

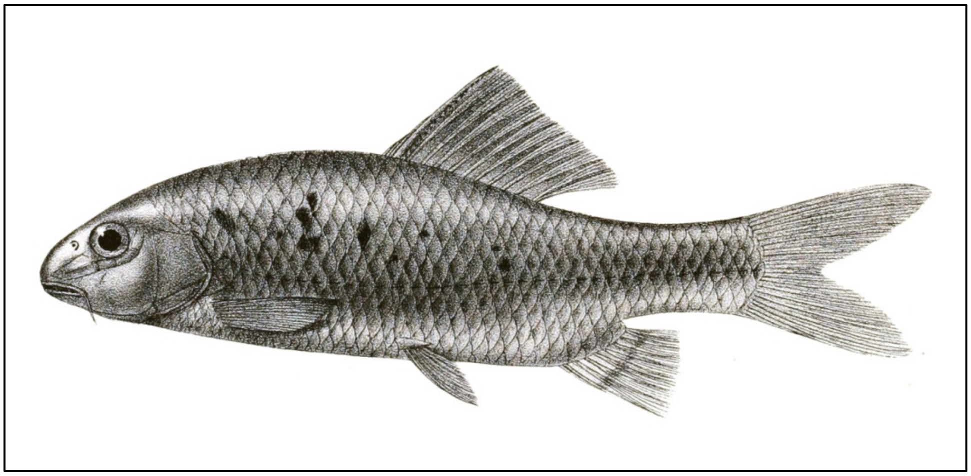
**Sources.** Type material:- *Cyprinion tenuiradius* (NMW 52808, NMW 52809, NMW 52810, NMW 52811, NMW 52812, NMW 52813, NMW 52814, NMW 52815 and NMW 52816).

Iranian material:- CMNFI 1979-0020, 56, 21.1-57.5 mm standard length, Fars, Mond River outside Kavar (29º11'N, 52º41'E); CMNFI 1979-0022, 8, 57.6-94.3, mm standard length, Iran, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0024, 3, 47.6-51.5, mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0026, 7, 27.0-69.3, mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0036, 4, 46.5-83.0 mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0054, 14, 37.4-64.1 mm standard length, Fars, Shur River tributary (ca. 28º58-29º03'N, ca. 52º34-35'E); CMNFI 1979-0057, 7, 19.6-35.5 mm standard length, Fars, stream 4 km from Shapur (29º49'N, 51º34'E); CMNFI 1979-0075, 123, 21.3-142.4 mm standard length, Fars, Mond River at Pol-e Kavar (29º11'N, 52º41'E); CMNFI 1979-0085, 1, 83.6 mm standard length, Fars, Hosseinabad (no other locality data); CMNFI 1979-0109, 5, 63.2-100.2 mm standard length, Fars, Mond River at Shahr-e Khafr (28º56'N, 53º14'E); CMNFI, 1979-0120, 8, 14.5-35.1 mm standard length, Bushehr, Dalaki River near Konar Takhteh (29º28'N, 51º21'E); CMNFI 1979-0128, 7, 19.2-103.8 mm standard length, Fars, Shur River between Atashkadeh and Firuzabad (28º51'N, 52º31'E); CMNFI 1979-0129, 39, 20.0-85.7 mm standard length, Fars, spring 2 km north of Farrashband (28º54'N, 52º04'E); CMNFI 1979-0131, 19, 16.4-41.7 mm standard length, Fars, Abarak River (28º38'N, 52º49'E); CMNFI 1979-0132, 65, 15.2-100.1 mm standard length, Fars, Shur River 54 km from Firuzabad (28º35'N, 52º58'E); CMNFI 1979-0133, 50, 45.6-95.5 mm standard length, qanat stream near Qir (28º27'30''N, 53º03'E);

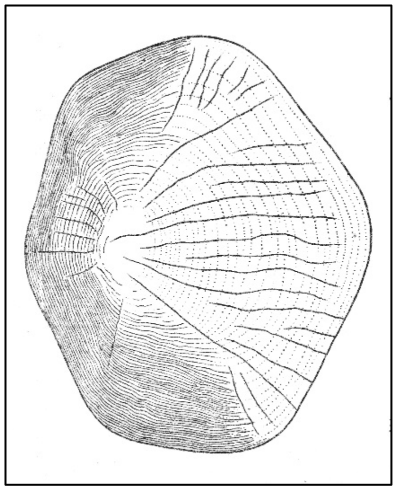
CMNFI 1979-0135, 18, 21.8-49.2 mm standard length, Fars, tributary to Mond River (28º08'N, 53º10'E); CMNFI 1979-0157, 4, 23.6-85.4 mm standard length, Fars, qanat stream at Hadiabad (28º52'N, 54º13'E); CMNFI 1979-0163, 3, 74.6-105.0 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0164, 21, 58.2-106.8 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0193, 1, 36.3 mm standard length, Fars, river 8 km from Darab (28º45'N, 54º27'30"E); CMNFI 1979-0196, 1, 59.9 mm standard length, Fars, qanat and pool at Khanehnehrin (28º50'N, 53º31'30"E); CMNFI 1979-0197, 1, 51.3 mm standard length, Fars, spring and stream 33 km from Fasa (28º45'N, 53º25'E); CMNFI 1979-0198, 23, 22.3-57.7 mm standard length, Fars, stream at Tadovan (28º47'N, 53º24'30"E); CMNFI 1979-0200, 8, 29.0-46.1 mm standard length, Fars, Mond River tributary 13 km from Jahrom (28º36'N, 53º36'30"E); CMNFI 1979-0202, 12, 18.0-25.3 mm standard length, Fars, Mond River (29º01'N, 53º00'E); CMNFI 1979-0241, 18, 43.8-72.6 mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0347, 2, 105.2-106.7 mm standard length, Fars, Pol-e Berengie (29º27'30"N, 52º32'E); CMNFI 1979-0348, 4, 52.9-79.1 mm standard length, Fars, stream at Somduldul (ca. 29º28'N, ca. 52º32'E); CMNFI 1979-0396, 1, 39.6 mm standard length, Kohgiluyeh and Bowyer Ahmad, Kheyrabad River 20 km from Behbehan (30º32'N, 50º23'30"E); CMNFI 1979-0398, 23, 22.1-74.5 mm standard length, Kohgiluyeh and Bowyer Ahmad, stream in Zohreh River drainage (30º24'30"N, 50º37'30"E); CMNFI 1979-0399, 7, 24.4-91.3 mm standard length, Fars, stream in Zohreh River drainage (30º19'30"N, 51º15'E); CMNFI 1979-0404, 25, 20.2-127.9 mm standard length, Bushehr, stream 33 km south of Kaki (28º08'N, 51º47'E); CMNFI 1979-0405, 4, 33.5-36.7 mm standard length, Hormozgan, stream about 13 km north of Rostaq (28º29'N, 54º59'E); CMNFI 1979-0497, 1, 85.6 mm standard length, Fars, Mond River at Band-e Bahman (29º11'N, 52º40'E); CMNFI 1979-0501, 17, 18.7-91.0 mm standard length, Fars, Mond River at Kavar (29º11'N, 52º41'E); CMNFI 1979-0504, 6, 95.7-103.3 mm standard length, Fars, stream at Pol-e Gaz in Lake Maharlu basin (no other locality data); CMNFI 1979-0789, 1, 164.6 mm standard length, Fars, Lake Parishan (29º31'N, 51º48'E); CMNFI 1991-0153, 1, 171.3 mm standard length, Khuzestan, Zohreh River (no other locality data); CMNFI 1993-0141, 1, 64.4 mm standard length, Bushehr, Dalaki River (29º28'N, 51º15'E); CMNFI 2007-0061, 2, 51.8-56.7 mm standard length, Fars, qanat pool at Ab-e Barik (ca. 27º52'N, ca. 54º09'E); CMNFI 2007-0062, 5, 39.2-45.6 mm standard length, Fars, qanat near Jahrom (ca. 27º52'N, ca. 54º09'E); CMNFI 2007-0063, 6, 39.6-63.4 mm standard length, Fars, Mond River outside Jahrom (28º36'N, 53º37'E); CMNFI 2008-0256, 2, 90.8-120.3 mm standard length, Fars, stream at Dimeh Mil-e Bala (30º06'52"N, 51º27'18"E); CMNFI 2008-0259, 4, 67.2-110.2 mm standard length, Fars, Atashkadeh Stream near Fasa (28º56'18"N, 53º38'54"E); CMNFI 2008-0263, 5, 77.6-110.8 mm standard length, Fars, Qarah Aqaj River (29º31'03"N, 52º15'E); CMNFI 2008-0268, 2, 31.3-31.9 mm standard length, Fars, possibly Lar (no other locality data); CMNFI 2008-0282, 1, 99.2 mm standard length, Fars, Kazerun (27º17'01"N, 51º50'25"E); CMNFI 2008-0288, 1, 89.1 mm standard length, Fars, Darreh Darvishan, Mimand (28º36'32"N, 53º02'27"E); USNM 205890, 2, 46.0-48.7 mm standard length, Fars, Lake Parishan (29º31'N, 51º48'E); ZSM 25705, 1, 107.0 mm standard length, Fars, Lake Parishan (29º31'N, 51º48'E).

***Cyprinion watsoni***

(Day, 1872)

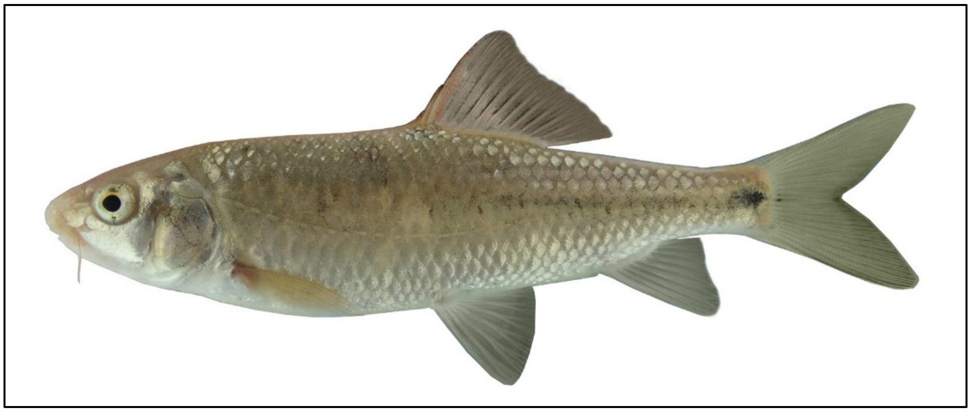


*Cyprinion watsoni*, after Day (1875-1878).

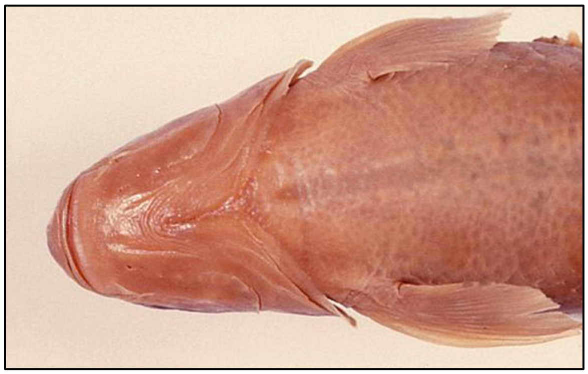


*Cyprinion watsoni*
(as *Scaphiodon macmahoni*),
dorsolateral scale,
after Annandale and Hora (1921).

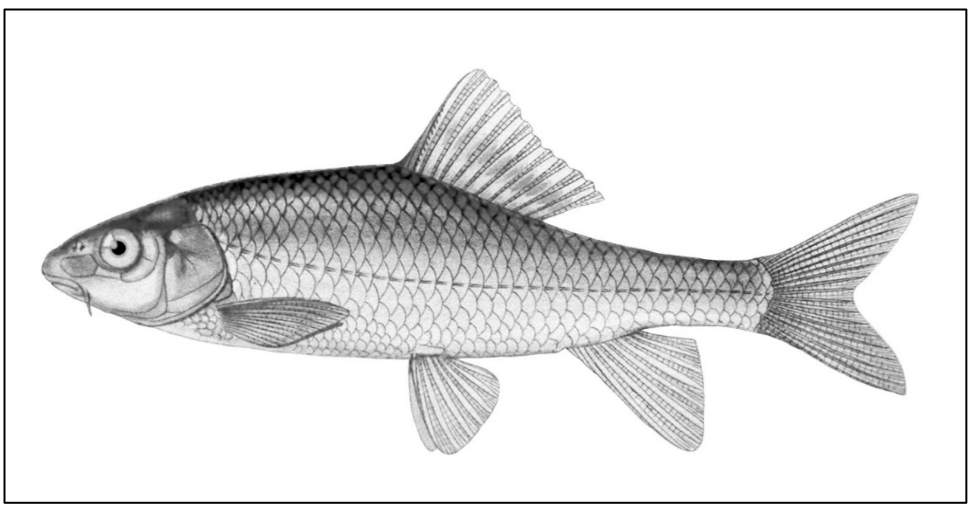
*Cyprinion watsoni*, Kerman, Gamatabad Qanat, Bam, Neil B. Armantrout.



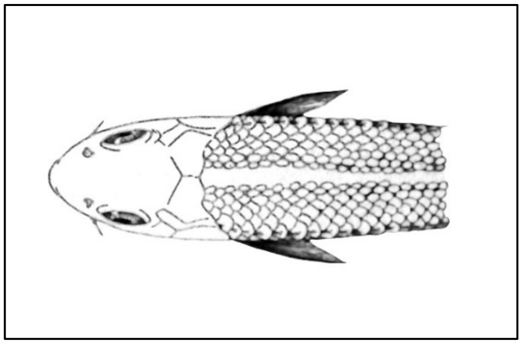
*Cyprinion microphthalmum* (*sic*), Qanat-e Ghasabe, Dasht-e Kavir basin, after Jouladeh-Roudbar *et al*. (2020).

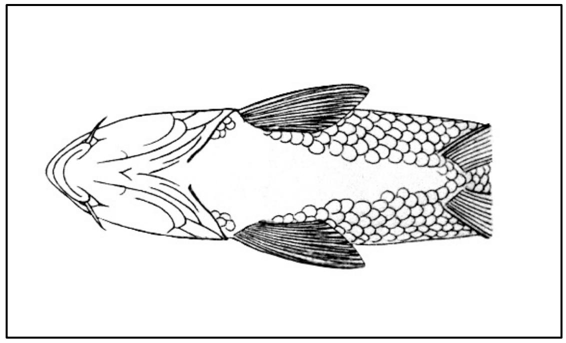


*Cyprinion watsoni*, ventral head, 110.2 mm standard length, CMNFI 1979-0314, Baluchestan, qanat at Karvandar, Brian W. Coad.

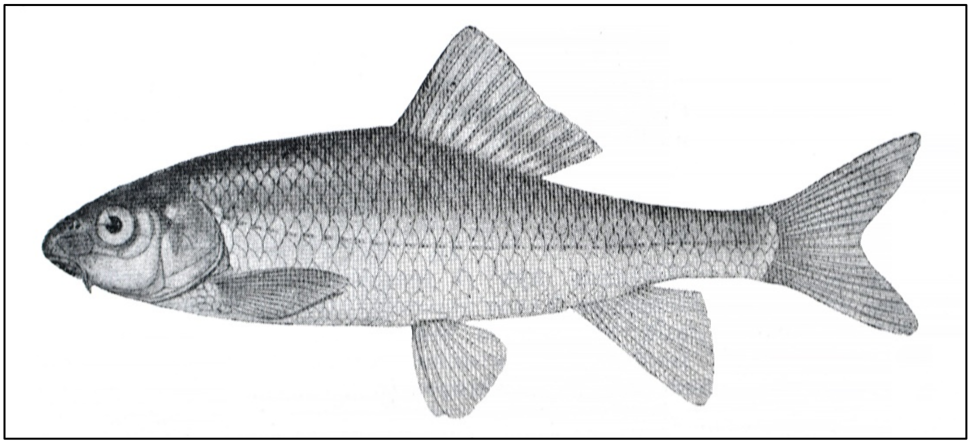


*Cyprinion watsoni* (as *C. irregulare*), 9.4 cm total length, ZISP 24337, Baluchestan, Mushkulak in the Kuhak region, after Berg (1949).





*Cyprinion watsoni* (as C. *irregulare*), as above, dorsal and ventral views, after Berg (1949).



*Cyprinion watsoni* (as *C. irregulare*? (*sic*)), 9.8 cm total length, ZISP 24015 (from ZISP 11711), Baluchestan, near Bampur, after Berg (1949).

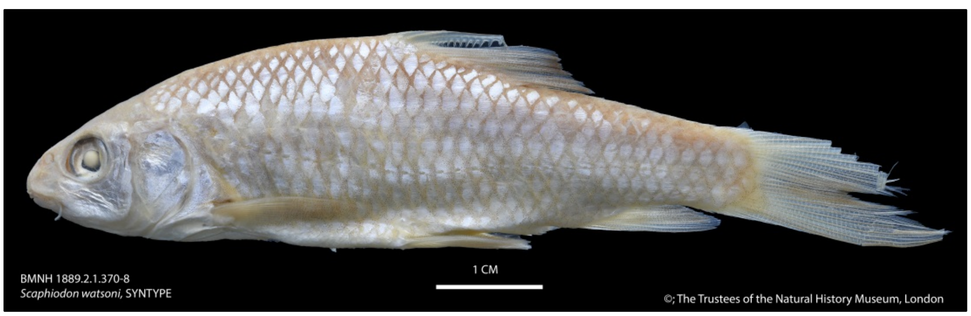
**Common names.** Butak-e Sistan (= Sistan butak, meaning of butak unknown); lotak Hendi (= Indian lotak), butak sharghi (for *C. microphthalmum*).

[Sabzug = *watsoni* and *microphthalmum* and sehrgoar - all in Pakistan; Indus lotak, Watson's kingfish; small eye butak (for *C. microphthalmum*)].

**Systematics.** *Scaphiodon irregularis* Day, 1872 (spelled *irregulare* in Berg (1949) when in the genus *Cyprinion*) described from "rivers in the Sind hills", India, formerly *Scaphiodon microphthalmus* Day, 1880 from "Quetta" (see below), formerly *Scaphiodon muscatensis* Boulenger, 1888 from Muscat, Oman (sometimes also regarded as a subspecies of *C. microphthalmum* but both *muscatensis* and *microphthalmus* are distinct (Freyhof *et al*. (2015, 2020); note Freyhof *et al*. (2020) has the spelling correctly as *muscatense* since *Cyprinion* is neuter), *Cirrhina afghana* Günther, 1889 from "Nushki (N. Baluchistan)" and "small river at Kushk (N.W. Afghanistan), Badghis" (this record at Koshk-e Kohneh is probably an error through mixed-up labels (Berg, 1949)), *Cyprinion kirmanense* Nikol'skii, 1899 (given as 1900 but possibly 1899 in the *Catalog of Fishes*, downloaded 23 May 2018) from "Schur-Ab in Kirmano orient.", *Cirrhina afghana* var. *nikolskii* Berg, 1905, *Scaphiodon macmahoni* Regan, 1906, *Scaphiodon baluchiorum* Jenkins, 1910 (see below for type locality), *Scaphiodon watsoni* var. *belense* Zugmayer, 1912 from the "Purali River, near Las Bela" (in Pakistani Baluchistan), *Scaphiodon readingi* Hora, 1923 from the "Salt Range, Punjab", India, and possibly *Cyprinion microphthalmum* infraspecies *nikolskii* Berg, 1949 described originally in part as *Cirrhina afghana* var. *nikolskii* Berg, 1905, and *Semiplotus dayi* Fowler, 1958 are synonyms.

*Semiplotus dayi* was coined by Fowler (1958) to replace *Scaphiodon aculeatus*, a misidentification by Day (1880) for *Chondrostoma aculeatum* (= *Capoeta aculeata*). Fowler thought that Day's fish represented a new species which he named *Semiplotus dayi*. Howes (1982) considered *Semiplotus dayi* to be a synonym of *Capoeta capoeta* (since Karaman (1969a) synonymised *Scaphiodon aculeata* with *C. capoeta*). Day's *Scaphiodon aculeatus* was placed in the synonymy of *Cyprinion microphthalmum* infraspecies *nikolskii* by Berg (1949).

Syntypes (or at least specimens examined by Day) of *Scaphiodon watsoni* described from rivers on the Sind Hills and the Salt Range of the Punjab, India are in the Zoological Survey of India, Calcutta under ZSI 2596 (1), the Natural History Museum, London under BM(NH) 1889.2.1:370-9 (10, but 14 in jar September 2007, 35.6-93.4 mm standard length), the Australian Museum, Sydney under AHS B.7751 (1), the Zoölogisch Museum, Universiteit van Amsterdam under ZMA 115924 (2) and ZMA 115925 (1), the Naturhistorisches Museum Wien under NMW 51671 (1), NMW 51672 (1) and NMW 51673 (1), the Museum für Naturkunde, Universität Humboldt, Berlin under ZMB 11042 (1) (132.6 mm standard length), the Rijksmuseum van Natuurlijke Historie, Leiden under RMNH 8704 (1) (or possibly RMNH 2552), the Zoological Institute, St. Petersburg under ZISP 8278 (4 but only 2 fish found by me, 63.6-79.6 mm standard length), and the Field Museum of Natural History, Chicago under FMNH 2303 (4, 34.0-72.5 mm standard length as examined by me) (Whitehead and Talwar, 1976; Nijssen *et al*., 1993; Eschmeyer *et al*., 1996; Ferraris *et al*., 2000). The three fish in the Naturhistorisches Museum Wien measured 86.6, 80.8 and 93.3 mm standard length respectively and are listed there as syntypes.



*Scaphiodon watsoni*, syntype, BM(NH) 1889.2.1:370-378.

*Scaphiodon watsoni*, syntype, NMW 51673, Brian W. Coad.

ZISP 8279 comprising three fish, 51.5-52.1 mm standard length, has the same data as ZISP 8278 and may also be types. It is not clear if these are all types, those in ZISP not being marked as types and those in BM(NH) being marked as "possible types"; they may include material simply collected by Francis Day.

A cotype of *Scaphiodon watsoni* var. *belense* (NMW 19833) measures 136.9 mm standard length. Eschmeyer *et al*. (1996) reported two fish under NMW 19833 although the Vienna card index in 1997 listed only one syntype under this number.

*Scaphiodon watsoni* var. *belense*, cotype, NMW 19833, Brian W. Coad.

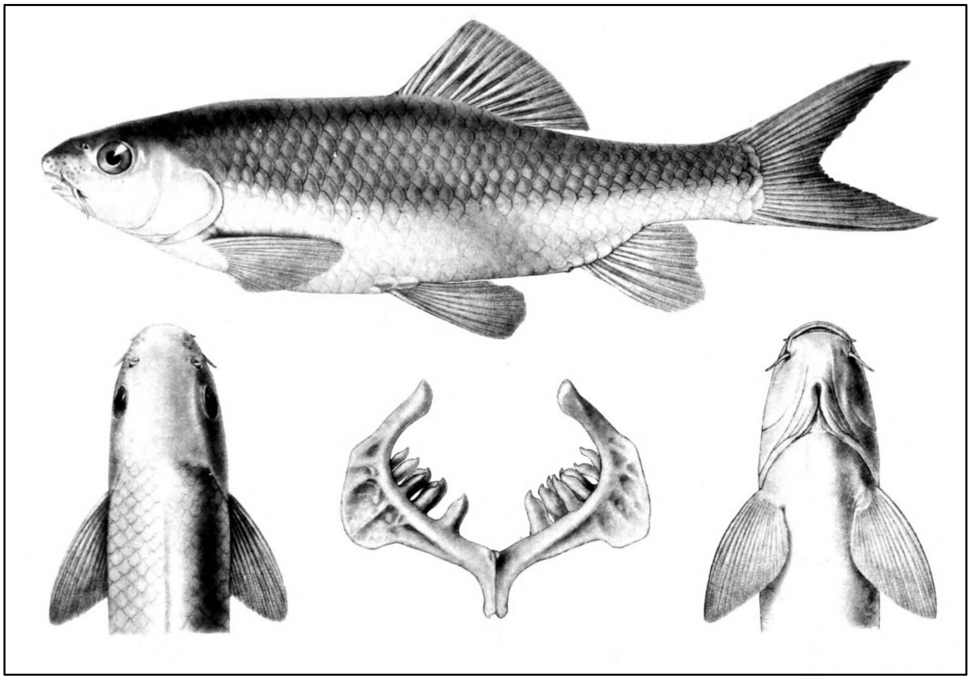
In the Zoological Survey of India, Calcutta there are single syntypes under ZSI F827/1 (a misprint for 8027), ZSI F8029/1, ZSI F8030/1 and ZSI F8031/1 (see also Menon and Yazdani (1968)). The remainder of 42 syntypes were in the Munich Museum but were destroyed in World War II (Neumann, 2006).

Types of *Scaphiodon microphthalmus* are probably lost. The species was described from two specimens taken at Quetta in Pakistan. One specimen was sent to the Florence Museum but a search failed to locate it and the other specimen has not been located (Whitehead and Talwar, 1976; Banister and Clarke, 1977). A fish measuring 130.1 mm standard length in the Naturhistorisches Museum Wien is listed as a possible syntype or a Day specimen (NMW 55897) and in the 1997 card index as "? Holotype" (*sic*).

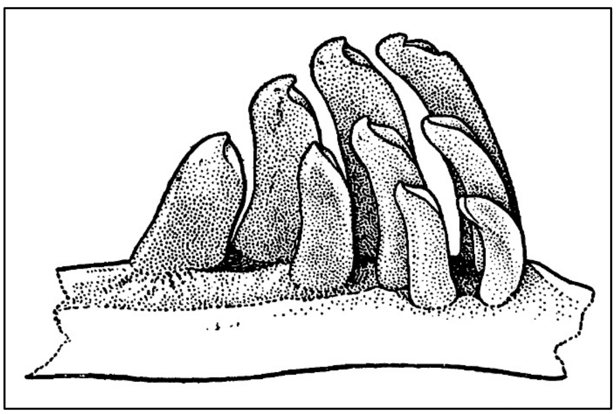
A syntype of *Scaphiodon irregularis* is in the Australian Museum, Sydney under AMS B.7883 (Ferraris *et al*., 2000) and other types are BM(NH) 1889.2.1:380-384 (5), MZUF 2373 (1), RMNH 4639 (1) and ZSI 2595 (lost) (*Catalog of Fishes*, downloaded 12 April 2018).

Syntypes of *Scaphiodon muscatensis* are in the Natural History Museum, London under BM(NH) 1885.11.7:35-40 (6, 66.4-89.3 mm standard length) and BM(NH) 1887.11.11:289-291 (3, 72.1-79.3 mm standard length) (Eschmeyer *et al*., 1996; personal observations).

Syntypes of *Scaphiodon readingi* are in the Zoological Survey of India, Calcutta under ZSI F10353/1 and ZSI 10354/1 (27) (*sic*, although the catalogue numbers seem to indicate only two fish) (Menon and Yazdani, 1968) and in the Zoological Museum of Moscow University (ZMMU) (P-1588) (1) (Pavlinov and Borissenko, 2001).

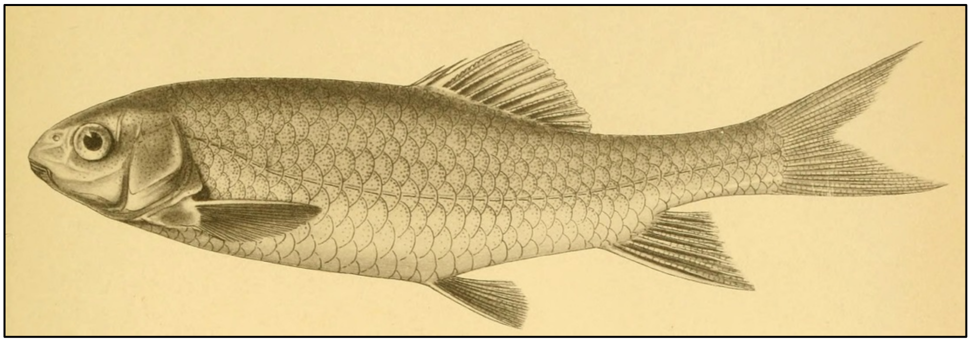


*Scaphiodon readingi*, body, dorsal head, pharyngeal arches, and ventral head, after Hora (1923).



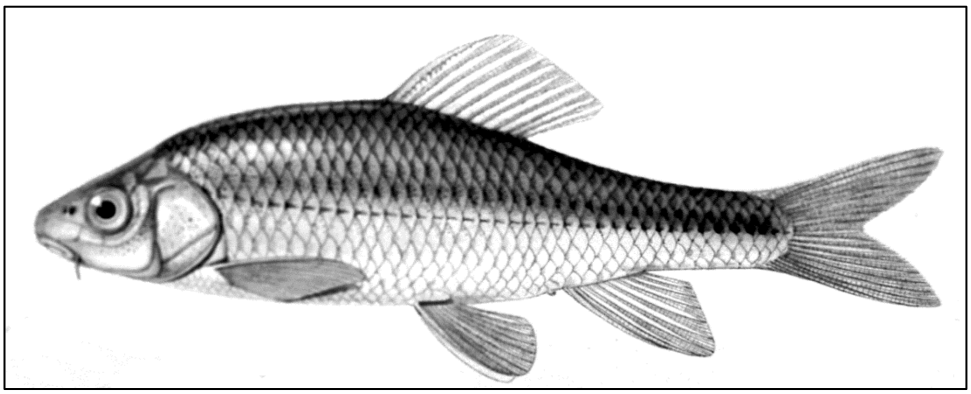
*Scaphiodon readingi*, pharyngeal teeth, after Hora (1923).

Three syntypes of *Scaphiodon baluchiorum* (ZSI F9398 to F9400) and one syntype of *Scaphiodon macmahoni* (ZSI F1239/1) are in the Zoological Survey of India, Calcutta (Menon and Yazdani, 1968). A syntype of *Scaphiodon macmahoni* measuring 58.6 mm standard length from "Seistan" is in the Natural History Museum, London and was labelled as *Cyprinion watsoni* (BM(NH) 1905.11.29:27). The type locality of *Scaphiodon baluchiorum* is "Gishtigan (Bampusht); Kalagan, 3,500 feet; Baluchistan". These localities are in Pakistani Baluchistan; Gishtigan being on the Kulushta River which drains into the Nihing River and then the Dashti River (Jenkins, 1910) (these are near the border of Iranian Baluchestan with the upper reaches of the Nihing being in Iran) and Kalagan possibly being the Kalugar River with headwaters in Iran and draining to the Hamun-i Mashkel in Pakistan. The type locality of *Scaphiodon macmahoni* is "affluents of the Helmand" (Regan, 1906), presumably an error for "effluents" or the delta of the Helmand.

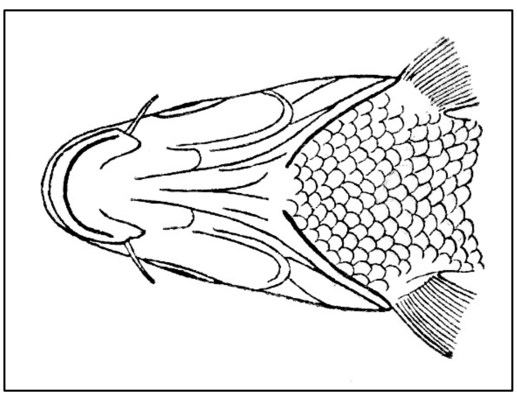


*Scaphiodon baluchiorum*, syntype, after Jenkins (1910).

The holotype of *Cyprinion kirmanense*, 61.6 mm standard length, is in the Zoological Institute, St. Petersburg under ZISP 11712 from "Schur-Ab in Kirmano orient. 27.VI.". This is possibly Shurabad at 27°41'N, 60°05'E after Roselaar and Aliabadian (2007).



*Cyprinion kirmanense*, holotype, 7.8 cm total length, ZISP 11712, Kerman, Shurab, after Berg (1949).

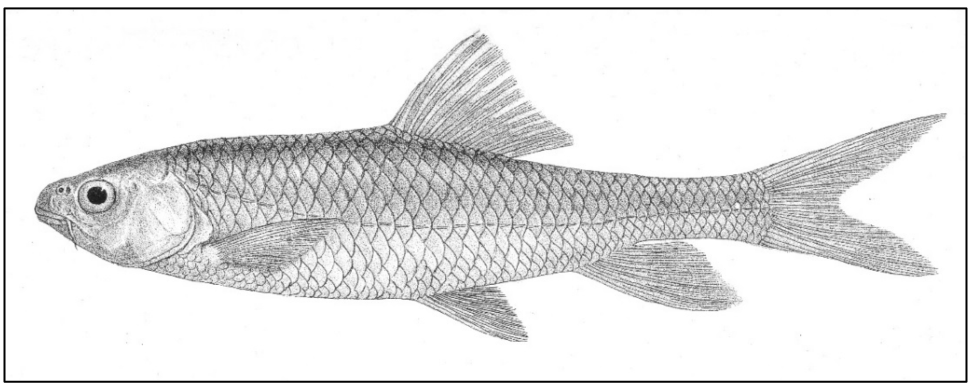


*Cyprinion kirmanense*, ventral head, as above, after Berg (1949).

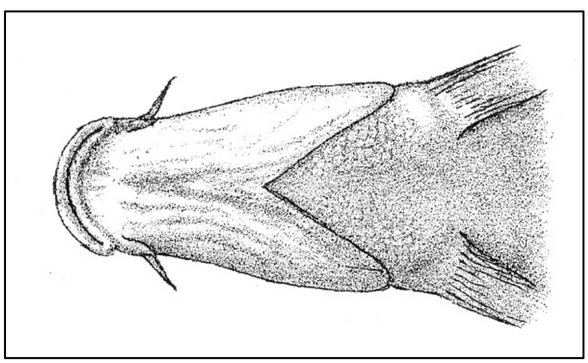
The five syntypes of *Cirrhina afghana* var. *nikolskii* are in St. Petersburg (ZISP 11709) and are from the "Bampur River, 27 VII 1898, N. Zarudnyi" according to Berg (1949) but he mentioned two additional fish with a somewhat deeper body, presumably also part of the type series. ZISP 11709 does have seven specimens, 43.0-79.1 mm standard length, with a date 15-27.VII.1898. Four syntypes of *Cirrhina afghana* measuring 74.6-83.0 mm standard length

from "Kushk" annotated Afghan. Boundary Comm. are in the Natural History Museum, London (BM(NH) 1886.9.21:150-154; note that 150-154 indicates there should be five fish) with a further six syntypes measuring 44.9-99.5 mm standard length labelled "Nushki" and also annotated Afghan. Boundary Comm. (BM(NH) 1886.9.21:155-159 - note this indicates there should be five fish in this jar and probably one fish has been mixed up). Additional syntypes are in the Zoological Survey of India, Calcutta under ZSI 11474-11476 (3) and ZSI 11479-11485 (7) (Eschmeyer *et al*., 1996).


*Cirrhina afghana*, syntype, BM(NH) 1886.9.21:155-159.

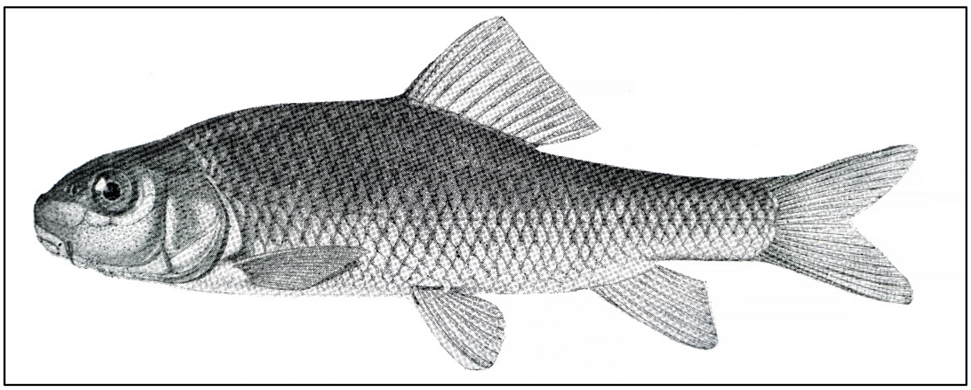


*Cirrhina afghana*, after Günther (1899).

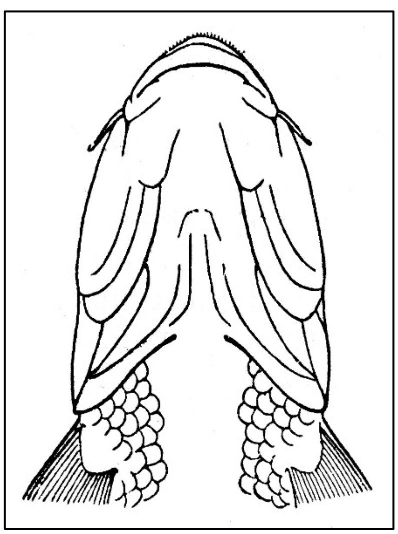


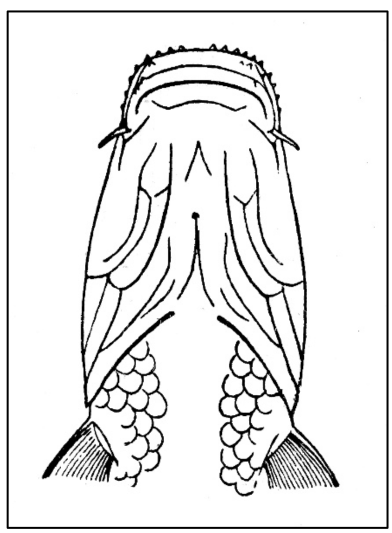
*Cirrhina afghana*, ventral head, after Günther (1899).

Berg (1949) placed *Cirrhina afghana* var. *nikolskii* in his *Cyprinion microphthalmum* infraspecies *nikolskii* (see also Berg (1933a)). This infraspecies occurs together with *Cyprinion microphthalmum* but differs by a stronger osseous ray in the dorsal fin which is serrated almost to the summit (Berg (1949) stated that transitions exist). The anterior belly region is scaleless also. ZISP 11709 fish mostly have their dorsal spines snapped off but one fish has osseous ray teeth between three-quarters and four-fifths along the spine and a second about three-quarters. ZISP 25406 from a qanat between Kerman and Bandar-e Abbas comprises 12 fish, 31.0-53.6 mm standard length, belonging to infraspecies *nikolskii* according to Berg (1949). These fish, of all sizes, have the last quarter to a third of the osseous spine in the dorsal fin unserrated. The mouth form varies. One large fish has a terminal mouth, moderately oblique in lateral view, and no strong horny layer on the lower jaw. Others have a u-shaped or horny jaw positioned on the lower head surface so there is no real gape in lateral view. Some small fish are transitional between the two types. Fin serration, mouth form and development of scales on the anterior belly seem to be widely variable within samples of *Cyprinion* from a single locality and presumably a single species.



*Cyprinion microphthalmum* infraspecies *nikolskii*, syntype, 9.7 cm total length, ZISP 11709, Baluchestan, Bampur River, after Berg (1949).





*Cyprinion microphthalmum* infraspecies *nikolskii*, syntypes, ventral heads, as above.

Berg (1949) recognised *Cyprinion watsoni belense* as a subspecies, rather than a variety as originally described, from Indian Ocean drainages of southeastern Iran and southwestern Pakistan (Baluchistan). It is distinguished by smaller scales (33-36) from the type form (31-34), hardly a sufficient criterion given the wide distribution range and individual variation shown by these fishes.

*Cyprinion watsoni* populations have not been adequately examined in southeastern Iran and most nominal species are referred to *Cyprinion watsoni*, the earliest available name for the taxon. *C. watsoni* is distinguished from other Iranian *Cyprinion* by having usually 9-11 dorsal fin branched rays (*macrostomus* and *tenuiradius* usually have 12-15; *C. milesi* also has a low dorsal ray count but has an oblique mouth, not transverse or arched (Berg, 1949)). Bianco and Banarescu (1982) considered that several subspecies may eventually be defined and that some of the names in synonymy here would then be used.

Berg (1949) also recognised *C. irregulare* as a distinct species with a low dorsal fin branched ray count as in *C. watsoni* but usually 37 or more scales in the lateral line, a scaleless groove on the back before the dorsal fin, and upper scale rows anteriorly arranged irregularly and not imbricate and *C. microphthalmum* with a low dorsal fin branched ray count as in *C. watsoni* but usually 37 or more scales in the lateral line, a scaleless groove on the back before the dorsal fin barely outlined, and upper scale rows anteriorly arranged regularly and imbricate. *C. microphthalmum* infraspecies *nikolskii* was described as having a strong dorsal fin spine with obvious teeth extending to the tip while typical *C. microphthalmum* has a weak ray with weak teeth only visible when the skin covering the fin is peeled away.

Berg (1949) later stated that no great importance should be attached to the upper row scale arrangement and the groove development - if the groove is well-developed then the upper row scales are irregular and this phenomenon can be seen in some *C. watsoni* and *C. microphthalmum* specimens. Berg then suggested that *C. irregulare* could be regarded as an infraspecies of *C. microphthalmum* as this type of condition occurs in *Capoeta fusca* and in *Garra rossica*. Under the heading *C. watsoni* Berg also gave mouth shape, scale arrangement, dorsal fin spine serrations, and body form as characters which can vary greatly. These observations serve to confirm the great variability in characters for these fishes. Large series of adults and young would be needed to adequately define some of these named species and subspecies.

Mirza (1969) reported *C. watsoni*, *C. microphthalmum* and *C. milesi* from western Pakistan and Iran, the former in Makran drainages and the latter two in the Mashkel (= Mashkid) River basin. The characters used to separate these taxa are an oblique mouth and head length contained less than 4.5 times in total length (= *C. milesi*), an arched mouth, head length more than 4.5 times in total length, scaleless strip on back conspicuous, and 33-36 lateral line scales (= *C. watsoni*), and a transverse mouth, head length more than 4.5 times in total length, scaleless strip on back hardly visible, and 37-40 lateral line scales (= *C. microphthalmum*). Sample sizes in this study were small (22 fish) and these characters showed considerable variation in larger samples and between fish of different sizes.

Note Howes (1982) and Mirza *et al*. (1991) also considered *Cyprinion microphthalmum* to be a valid species with *muscatensis* (= *muscatense*), *afghana*, *afghana* var. *nikolskii* and *baluchiorum* as synonyms. Howes placed *macmahoni* in *watsoni* rather than *microphthalmum* as Berg (1949) and Mirza (1969) did. Howes (1982) also included *irregularis*, *kirmanense* and *readingi* in *watsoni*.

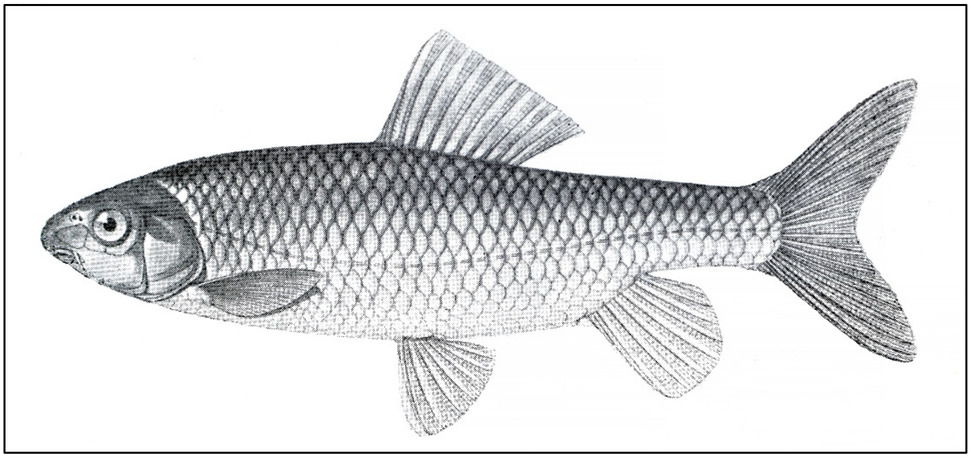
Many samples examined by me from a single locality, and presumably one species,

show considerable morphological variability in belly and back scalation, dorsal fin spine strength and size and extent of spine teeth, mouth shape, and presence of a horny edge on the lower jaw, as noted previously by Berg (1949). These characters have been used to identify subspecies or species within southeast Iran, here generally referred to as *C. watsoni* based on my material. Dorsal fin spine teeth can be at the base only or extend as much as three-quarters along the spine without any association with fish size. Mouth shape is discussed below.

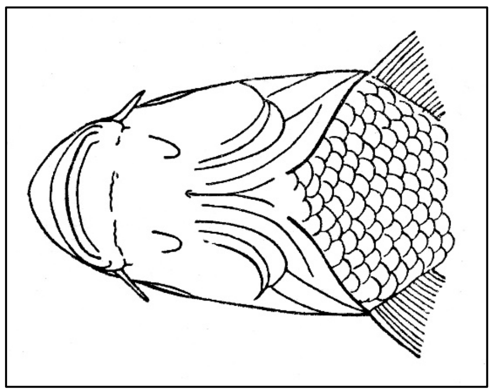
Freyhof *et al*. (2015, 2020) indicated that *C. microphthalmum* and *C. watsoni* are distinct on unpublished molecular data and other authors, as mentioned above, also indicated that they are distinct. Freyhof *et al*. (2020) stated that *C. watsoni* has a slightly inferior mouth, almost terminal, without a sharp cutting edge (edge often present in fish seen by me) in comparison with *C. muscatense* of the Arabian Peninsula. However, Nasri *et al*. (2018), studying 10 meristic and 12 morphometric characters in Iranian samples, found these characters widely overlapped in *C. microphthalmum* and *C. watsoni* and the species could not be distinguished. Nasri *et al*. (2019) also noted that the two species are difficult to distinguish morphometrically. *C. microphthalmum* at present is a cryptic species and cannot be readily identified in the field or as preserved material. Accordingly, I identify all southeastern Iranian *Cyprinion* (except possibly *C. milesi*) as *C. watsoni* while recognising that some may be *C. microphthalmum* ultimately recognisable by DNA studies or more detailed anatomical work. *C. microphthalmum* would be present, for example, in the Hamun-e Jaz Murian, Hamun-e Mashkid and Makran basins (Jouladeh-Roudbar *et al*., 2015; Esmaeili *et al*., 2017; Nasri *et al*., 2019) and possibly further west in the range of material referred to *C. watsoni* in the Hormuz basin (Eelood River after Nasri *et al*. (2018)). The two species may well occur syntopically but this too remains to be elucidated.

Within any large single sample of fishes from one locality in southeast Iran, with fish of diverse size and assuming they represent a single species, there is a progression from small fish with a u-shaped mouth and no keratinization of the lower lip to a sector or horizontal mouth with a strong and obvious keratinized lower lip edge. The u-shaped mouth is horizontal in lateral view. A horizontal mouth and absence of keratinization are reportedly distinguishing characters of *C. milesi*. Note that it is possible some fish may lose the keratin from the lower lip during collection, transport and preservation (although u-shaped mouths generally lack keratin and this does not appear to be due to accidental loss). Some fish, of about equal size within one sample, may have a sector mouth with keratinized lower lip and a u-shaped mouth without a keratinized lower lip. Even in a collection of small fish, some may show a shallow arch with a horny or keratinized edge and some a u-shaped mouth without keratin. It could be that a u-shaped juvenile mouth is retained in some adults. An example is CMNFI 1979-0412. Ten larger fish at 96.3-122.2 mm standard length had u-shaped mouths while a single large specimen, 91.9 mm standard length, had a shallowly arched mouth with a keratinized edge. This variation renders identification of *C. milesi* difficult. Again, I refer my material from southeast Iran to *C. watsoni* while recognising that, as with *C. microphthalmum* included in *C. watsoni*, some material may be *C. milesi*. Presumably molecular studies could identify material to species distinct from *C. watsoni* and then careful analyses might reveal external characters that could be used to identify fish in the field and as preserved material in collections.

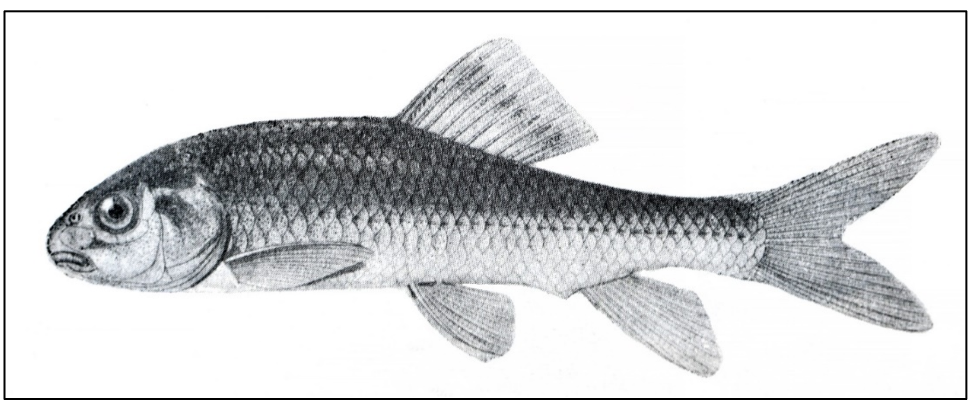
The following illustrations from Berg (1949) show material he considered to be *Cyprinion microphthalmum*.



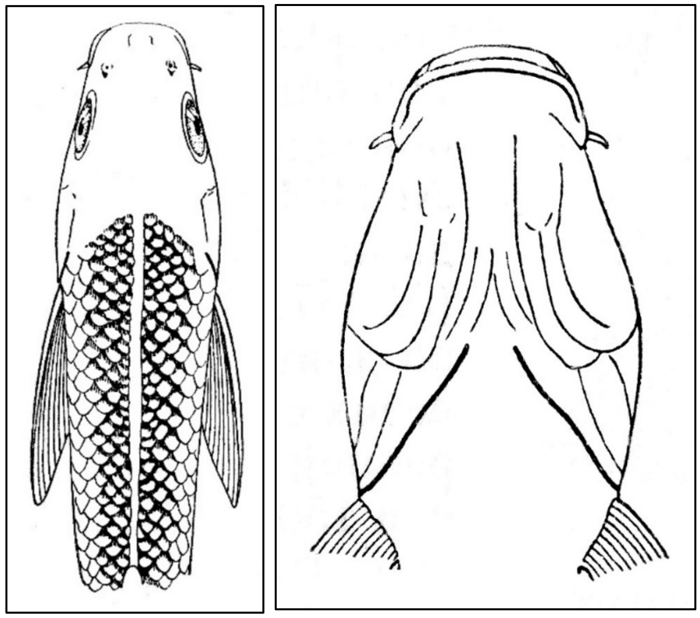
*Cyprinion microphthalmum*, 12.0 cm total length, ZISP 24094, Iran, Baluchestan, after Berg (1949).



*Cyprinion microphthalmum*, ventral view of head, as above.



*Cyprinion microphthalmum*, 9.3 cm total length, ZISP 11711, Baluchestan, Kaskin near Bampur, after Berg (1949).



Dorsal and ventral views of head of *Cyprinion microphthalmum*, same specimen as above, after Berg (1949).

Nasri *et al*. (2018) examined three single populations identified as *C. milesi*, *C. microphthalmum* and *C. watsoni* and separated *C. milesi* from *C. watsoni* by several morphometric characters (least head height/body depth, least body depth/standard length, least dorsal fin base length/standard length and least dorsal fin height/standard length) but these all overlap in tables. Pectoral fin branched ray counts were 13-14 in *milesi* but 10-12 in *microphthalmum* and *watsoni*. My counts show a range for nominal *watsoni* of 11-18 (see table below). Eye diameter from Nasri *et al*. (2018) at 5.2-5.5 (mean 3.9, *sic*) for *microphthalmum* seems to agree with the species name (in contrast to 2.6-5.1 (mean 5.4, *sic*) for *milesi* and 2.9-4.9, mean 3.7, for *watsoni*). The means for the first two species are presumably reversed. My material did not show adult fish with such a small eye diameter. Sample sizes, albeit for single populations, were relatively good in Nasri *et al*. (2018) (143 in *microphthalmum*, 32 in *milesi* and 67 in *watsoni*) but fish were not separated by sex as it was stated there is no sexual dimorphism. Range in size of samples was not given and this too may affect results even with corrections made for size. A combination of morphometric characters, or mean values, may distinguish the three species when examined as populations but individuals are not separable on this data.

Bagheri Dorbadam and Golzarianpour (2013) compared three qanat populations from eastern Iran (Bidokht, Gonabad and Nishapur in Razavi Khorasan) finding the first significantly different with a deeper caudal peduncle and wider head. The latter two qanats are connected while the first is isolated. The Bidokht population had a high rate of malformations (22 malformed to 38 normal fish). Nasri *et al*. (2014) compared fish from the Hormuz (2 populations), Makran (4), Jaz Murian (2) and Mashkid (1) basins and used shape data. The Bastak population in the Hormuz basin separated strongly from the others on least body depth, longer head, more oblique mouth and shorter caudal peduncle, and all populations showed differences to varying degrees. Assuming these fish in these two studies are all *C. watsoni*, the observed variation between populations confirms the difficulty of identifying C. *microphthalmum* morphometrically.

Zamani Faradonbe and Keivany (2018) examined 109 fish from the Minab, Sarbaz and Shur rivers for 19 morphometric characters and found significant differences among the populations in all but three characters.

**Key characters.** The arched mouth and 9-12, usually 10-11, dorsal fin branched rays serve to identify this species.

**Morphology.** The body is compressed and moderately deep, although some fish can be quite slender. The body is deepest at the dorsal fin origin or slightly in front of it. The predorsal profile is convex. The caudal peduncle is compressed and moderately deep. The head is rounded or may be straight to slightly concave in profile. The eye is in the anterior half of the head. Larger fish may develop a snout flap overhanging the moderately thick upper lip. Young fish have a more horseshoe-shaped mouth than larger and older fish where the mouth is a shallow arch, almost straight (a sector or horizontal mouth). The lower jaw has a sharp cutting edge despite the report of no edge in Freyhof *et al*. (2020). The barbel is thin and can extend back as far as the mid-eye level. The dorsal fin spine is weak to moderate with small- to moderate-sized denticles extending about 60% or more along the spine, quite variable. The dorsal fin margin is straight to slightly emarginate. The dorsal fin origin lies slightly or more evidently anterior to the level of the pelvic fin origin. The depressed dorsal fin extends back level with the beginning of the anal fin or just in front of its origin. The caudal fin is deeply forked with pointed tips. The anal fin is rounded and does not extend back to the caudal fin base but may almost reach it in some. The pelvic fin has a rounded to straight margin and does not extend back to the anal fin origin. The pectoral fin is rounded and does not extend back to the pelvic fin origin.

The dorsal fin has 3-4 unbranched and 9-12 branched rays, the last unbranched ray of the dorsal fin being variably serrated and thickened. The extent of serrations appears to vary independently of size, from only near the base to three-quarters or more of the spine length. The distal portion is thin and flexible. The anal fin has 1-3, usually 3, unbranched and 6-8, usually 7 branched rays. In Iranian specimens, 89.7% of 419 fish had 7 anal fin branched rays, the remainder having 6 branched rays. Pectoral fin branched rays 10-18, usually 15-16 (Nasri *et al*. (2018) gives 10(70), 11(27) or 12(3)), and pelvic fin branched rays 6-9, usually 8 (usually 7 in Nasri *et al*. (2018)). Lateral line scales 31-43. Scales have well-developed anterior radii as well as posterior and some lateral radii. The scale focus is almost central on mid-flank scales. There is a naked median strip on the back in front of the dorsal fin, about one scale wide, in some fish. Some fish may show poor imbrication of scales on the belly, scales embedded in the skin, obvious or even absent, and upper anterior flank can also be poorly imbricated. Total gill rakers number 8-18, reaching to or past the adjacent raker when appressed. Total vertebrae number 36-40. The species rarely has a tripartite gas bladder, usually it is bipartite (Mirza, 1971 - for his *C. microphthalmum*). Pharyngeal teeth are 2,3,4-4,3,2 or 2,3,5-5,3,2, with spoon-shaped crowns.

Meristic values for Iranian specimens are:-

| Locality/Dorsal Fin Rays | 9 | 10 | 11 | 12 | x | S.D. |
|---|---|---|---|---|---|---|
| Hamun-e Mashkid | | 16 | 3 | | 10.2 | 0.375 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Hamun-e Jaz Murian | 3 | 15 | 5 | | 10.1 | 0.596 |
| Dasht-e Lut | 2 | 50 | 4 | | 10.0 | 0.328 |
| Makran | 1 | 29 | 3 | | 10.1 | 0.348 |
| Hormuz | 2 | 144 | 124 | 7 | 10.5 | 0.562 |
| Sirjan | 1 | 3 | 7 | | 10.5 | 0.688 |

| Locality/Pelvic Fin Branched Rays | 6 | 7 | 8 | 9 | X | S.D. |
|---|---|---|---|---|---|---|
| Hamun-e Mashkid | | 6 | 13 | | 7.7 | 0.478 |
| Hamun-e Jaz Murian | | 1 | 21 | 1 | 8.0 | 0.302 |
| Dasht-e Lut | | 1 | 54 | | 8.0 | 0.135 |
| Makran | | | 33 | | 8.0 | 0.000 |
| Hormuz | 2 | 31 | 237 | 8 | 7.9 | 0.400 |
| Sirjan | | 2 | 9 | | 7.8 | 0.405 |

| Locality/Pectoral Fin Branched Rays | 11 | 13 | 14 | 15 | 16 | 17 | 18 | x | S.D. |
|---|---|---|---|---|---|---|---|---|---|
| Hamun-e Mashkid | | | | 9 | 10 | | | 15.5 | 0.513 |
| Hamun-e Jaz Murian | | | 1 | 8 | 11 | 2 | 1 | 15.7 | 0.864 |
| Dasht-e Lut | 1 | | 2 | 14 | 31 | 8 | | 14.8 | 0.879 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Makran | | | 1 | 14 | 15 | 3 | | 15.6 | 0.704 |
| Hormuz | | 1 | 46 | 111 | 99 | 20 | 1 | 15.3 | 0.863 |
| Sirjan | | | 4 | 4 | 3 | | | 14.9 | 0.831 |

| Locality/Total Gill Rakers | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | x | S.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hamun-e Mashkid | | | 1 | | 4 | 3 | 4 | 3 | 4 | | | 13.8 | 1.718 |
| Hamun-e Jaz Murian | | | 3 | 4 | 10 | 4 | 1 | | | 1 | | 12.0 | 1.492 |
| Dasht-e Lut | | 1 | 7 | 8 | 16 | 12 | 10 | 2 | | | | 12.2 | 1.427 |
| Makran | | | 1 | 6 | 9 | 4 | 8 | 3 | | 1 | 1 | 13.0 | 1.794 |
| Hormuz | 3 | 7 | 33 | 45 | 64 | 60 | 41 | 10 | 2 | 1 | | 12.2 | 1.569 |
| Sirjan | | | 2 | 2 | 1 | 5 | 1 | | | | | 12.1 | 1.375 |

| Locality/ Lateral Line Scales | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | x | S.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hamun-e Mashkid | | | 1 | 3 | 9 | | 1 | 1 | 1 | 2 | 1 | 38.1 | 2.368 |
| Hamun-e Jaz Murian | | | 1 | 9 | 11 | 1 | 1 | | | | | 36.7 | 0.832 |
| Dasht-e Lut | | | 5 | 12 | 26 | 10 | 2 | 1 | | | | 36.9 | 1.032 |
| Makran | | | 2 | 1 | 17 | 8 | 4 | | 1 | | | 37.5 | 1.148 |
| Hormuz | 1 | 2 | 17 | 57 | 99 | 72 | 20 | 7 | 3 | | | 37.2 | 1.224 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sirjan | | | | 3 | 4 | 3 | 1 | | | | | 37.2 | 0.982 |

The holotype of *Cyprinion kirmanense* has 10 dorsal fin branched rays, 7 anal fin branched rays, 15 pectoral fin branched rays, 8 pelvic fin branched rays, 37 lateral line scales and 13 total gill rakers (not in above tables).

**Sexual dimorphism.** Males have snout tubercles and tubercles on the anal fin rays (Regan, 1906; Jenkins, 1910; Berg, 1949). Large tubercles are found on the snout in front of the nostrils, the top of the head, and in rows on the rays of the caudal and anal fins, following the ray branching, in a fish not yet fully mature (40.1 mm standard length, CMNFI 1979-0416, 21 March 1978). ZMB 11042 (132.6 mm standard length, see above) has tubercles thickly present on the snout extending back to the nostrils and then to the eyes, scattered all over the sides of the head, absent on top of the head (may be lost in this old specimen) and large tubercles on anal fin rays near the tip. Other specimens (e.g., CMNFI 1979-0186, 67.1 mm standard length, 29 January 1977) have large tubercles around the snout, nostril to nostril level, and lining most of the length of the anal fin rays, few and small tubercles on the caudal fin, and few and small tubercles on the scale margins from the dorsal to the caudal fin on the upper flank and post-dorsal fin back. Tubercles in other fish may also be found additionally less developed and scattered on the cheek, behind the eye and on the operculum, and small and scattered on top of the head. There is a depression in front of the nostrils in adult males.

**Colour.** The back and upper flank are dark or copper brown, golden or dark olive, light green-brown or brown-grey, sometimes with bluish or orange tinges, fading to a light or yellowish-pink on the lower flanks and belly. The flank scales are silvery and may be outlined in black. Black spots may be present along the flank as may be an orange stripe or a series of 7-9 orange spots above the lateral line anteriorly. The orange colour may be deep, almost red. Occasionally, there may be an orange spot below the lateral line. There may be a vertical orange line over the cleithrum or a spot at its postero-ventral corner. In some fish the whole cleithrum area is red-orange. The operculum, preoperculum and cheek can be iridescent blue. The bases of the pectoral and pelvic fins and part of the operculum may also be pink or orange-coloured. Young have a fine black streak above the lateral line. The dorsal and caudal fins are lead-coloured to black, with pigment concentrated on the membranes, and other fins are pink to yellowish. All the fins except the paired fins may be hyaline. There can be a black caudal base spot, quite marked in some fish, particularly smaller ones, becoming more diffuse in older fish and also diffuse in some young fish. Larger fish (> 10.0 cm) lack a caudal spot. Young fish also have a spot on the flank at the anterior dorsal fin base, at mid-base and at the end of the base, or only the anteriormost spot. Young may also have up to five blotches on the upper to mid-flank and spots or a stripe post-dorsally on the back. The peritoneum is black or dark brown.

**Size.** Attains 23.0 cm (Zugmayer, 1912).

**Distribution.** This species is found from southeastern Iran east to India. In Iran, it is recorded from the Bejestan, Dasht-e Lut, Hamun-e Jaz Murian, Hamun-e Mashkid, Hormuz, Kerman-Na'in, Makran, Sirjan and Sistan basins, including various qanats, springs and streams, not all named, but listed in the **Sources** below and not repeated here. Found in the Dasht-e Lut basin in the Ab Barik, Adori, Fahraj, Ghoyeh, Groh, Khamrotag, Kohpayeh and Koli rivers; in the Hamun-e Jaz Murian basin from the Baft, Bampur, Halil, Halil-Kouchak, Rudbar, Shakim and Shur rivers and the Bampur Dam; in the Hamun-e Mashkid basin from the

Khanzaman, Mashkid and Tahlab rivers; in the Hormuz basin from the Dehsheikh, Droudi, Galehgah, Goodar, Hasan Langi, Jafari, Jalabi, Kul, Mehran, Minab, Narmand, Rasul, Sarzeh and Shur rivers, the Marm Cascade, the Sar Khun oasis and the Ab Garm-e Ganow; and in the Makran basin from the Bahu Kalat, Gaz, Geh, Geru, Jaghin, Karvandar, Kash, Mazaei, Minab, Nahang, Qabrik, Rask Gando, Rudan and Sarbaz rivers (Berg, 1949; Spillman, 1972; Bianco and Banarescu, 1982; Jalali *et al*., 1995, 2005; Abdoli, 2000; Ebrahimi *et al*., 2002; Bagheri *et al*., 2010; Pazooki *et al*., 2012; Bagheri Dorbadam *et al*., 2013; Malekzehi *et al*., 2013, 2014; Mirashrafi Langroudi *et al*., 2013; Nasri *et al*., 2013, 2014; Yazdanpanah Goharrizi, 2014; Esmaeili *et al*., 2015; Jouladeh-Roudbar *et al*., 2015; Shahi *et al*., 2015; Nasri *et al*., 2018; Ghasemi Rezvani *et al*., 2020). Jouladeh-Roudbar *et al*. (2020) stated that it may be limited to Pakistani waters and needed further study.

A record from the Gamasiab River of the Tigris River basin is an error (Biukani *et al*., 2013).

**Zoogeography.** The occurrence of this species (as *C. microphthalmum* in Banister and Clarke (1977)) in Oman across the Straits of Hormuz is a result of the 120 m lowered sea level from 100,000 B.P. to 10,000 B.P. The Tigris-Euphrates then ran down the Persian Gulf and presumably provided ready access across it. Banister and Clarke (1977) commented that it is surprising that only one species made the crossing but nothing is known of the climate during this 90,000-year period nor of the composition of the Iranian fish fauna. It may well have been quite impoverished. Omani *Cyprinion* are now recognised as a distinct speces (*C. muscatense*) – see above under Systematics.

Hora (1956) described fish paintings on pots from Nal in Pakistani Baluchistan dating from the third millennium B.C. One of the species not clearly represented is a *Cyprinion*, now found in that area (not extinct as Banister (1980) would have it). This potentially shows how the ichthyofauna in Southwest Asia can change over relatively short periods of time; the changes over 100,000 years must have been considerable and not readily traceable.

Dorsal fin branched rays have moderately strong modes of 10 for the Hamun-e Mashkid, Hamun-e Jaz Murian, Dasht-e Lut and Makran basins but modes of 10 and/or 11 for Hormuz and Sirjan, the westernmost basins. *C. watsoni* may be showing some introgression with *Cyprinion* species to the west which have higher counts. However, subsamples within the Hormuz basin do not show a clear pattern of higher modes or means towards the west.

Zoogeographical comments are also under the genus above.

**Habitat.** This species is found in rivers, streams, lakes, dams, ponds, marshes, springs, jubes (= irrigation channels) and qanats. Several habitat types are shown below. Kiabi and Abdoli (2000) found this species to be the commonest and to have the widest range in Hormozgan Province. It has been caught at 30°C water temperature in a jube (= irrigation channel) on 6 May 1977 at Maran Galu in Kerman (CMNFI 1979-0219) and at 31-36°C on 21 March 1978 in the Ginao hot spring below the falls (CMNFI 1979-0416).

Habitat of *Cyprinion watsoni* (and the snakehead *Channa gachua*), CMNFI 1979-0220, Kerman, irrigation ditch or jube south of Jiroft, 6 May 1977, Brian W. Coad.

Habitat of *Cyprinion watsoni*, CMNFI 1979-0311, Baluchestan, Bampur River at Malakabad at dusk, 30 November 1977, Brian W. Coad.

Habitat of *Cyprinion watsoni* (and *Paraschistura bampurensis* and *Aphaniops dispar*), CMNFI 1979-0313, Baluchestan, Bampur River at Bangharabad, 1 December 1977, Brian W. Coad.

**Age and growth.** Esmaeili and Ebrahimi (2006) gave a *b* value of 2.952 based on 23 Iranian fish measuring 8.34-13.38 cm total length. Bagheri Dorbadan *et al*. (2013) examined 161 fish from three qanats in Razavi Khorasan finding males dominant in two and females in one qanat, the lowest mean condition factor was in females from Beidokht (= Bidokht) qanat (1.17) and the highest in females of Nishapur qanat (1.59), and growth was negative allometric in two qanats and positive in one, indicating great variability in growth characteristics in different habitats and environmental conditions, important for conservation and management of the species. Mirashrafi Langroudi *et al*. (2013) examined 428 fish, 3.2-14.3 cm total length, from the Karvandar River in southeast Iran finding a male:female sex ratio of 1:1.18 (not significantly different), and the length-weight relationships were $W = 0.0088TL^{3.136}$ for males, $W = 0.009TL^{3.112}$ for females and $W = 0.0088TL^{3.132}$ for all fish, indicating positive allometric growth. Esmaeili *et al*. (2014) gave a *b* value for 43 fish from the Hormuz basin, 5.1-9.94 cm total length, as 3.08 and for 39 fish from the Makran, 4.6-12.0 cm total length, as 2.98, total 3.03.

**Food.** Ghasemi Rezvani *et al*. (2020) examined 392 fish from the Marm Cascade, Hormozgan and found they were herbivores at a rate of 98.8% with Bacillariophyta (diatoms) at 92.67%, Cyanophyta at 5.34%, Chrysophyta at 0.28%, Chlorophyta at 0.29%, Crustacea at 0.04%, Mollusc at 0.04% and Foraminifera at 0.01%. Fish in the Sarbaz River, Baluchestan were seen “cleaning” rocks in December 1977 (CMNFI 1979-0323). Gut contents are primarily herbivorous items including filamentous algae such as *Cladophora* and *Spirogyra*, and a wide range of diatoms but some insect material is also found in Pakistan (Mirza, 1969; Farooq *et al*., 1996).

**Reproduction.** Up to 150 eggs were recorded by me in fish from the Ab Garm-e Ganow with a diameter of 1.2 mm. Mirashrafi Langroudi *et al*. (2013) found fish from the Karvandar River had egg diameters up to 1.58 mm, absolute fecundity was 360-4,413 eggs, relative fecundity was 25.5-302.1 eggs/g, the gonadosomatic index peaked at 4.84 for males

and 7.66 for females in May, and reproduction occurred around April-June.

Spawning took place in Pakistan at Islamabad from mid- to late March to mid-April (Shaikh and Jalali, 1989, 1991) and near Islamabad (33.3°N, 73.0°E) in April and May (Shaikh and Hafeez, 1993). Gonads began to develop in December as photoperiod and temperature rose but a continuing warm temperature was the predominant factor for spawning to occur; a fall in temperature halted spawning. Eggs were dark yellow when mature, testes creamy when ripe. Spawning occurred once a year.

**Parasites and predators.** Males were reported as having snout tubercles and tubercles on the anal fin rays (Regan, 1906) but these were the encysted glochidia of a unionid mollusc (B. Prashad in Annandale and Hora (1920)). Jalali *et al*. (1995) described a new species of monogenean, *Dactylogyrus pallicirrus*, from fish taken in the Shur River, a Halil River tributary in the Hamun-e Jaz Murian basin. Jalali *et al*. (2005) summarised the occurrence of *Gyrodactylus* species in Iran and recorded *Gyrodactylus* sp. for fish from the Minab and Halil rivers. Pazooki *et al*. (2012) found the nematodes *Hepaticola petruschewkii* and *Rhabdochona denudata* and *R. macrostoma* in fish from Kerman (Abshur, Halil, Jafarabad and Konarooleh rivers). Malekzehi *et al*. (2013, 2014) recorded *Lernaea* sp. from fish identified as *C. microphthalmum* in the Mashkel River basin. Yazdanpanah Goharrizi (2014) recorded *Saprolegnia* from fish in the Baft River, Kerman.

Mobaraki (2015) recorded this species in the diet of mugger crocodile (*Crocodylus palustris*) in southeastern Iran.

**Economic importance.** This species is of no economic importance although Butt (1995) suggested that it could be a food source in Pakistan, occurring in shoals of considerable size in rivers that otherwise support little in the form of aquatic protein. It could be cultured as food and as a forage fish.

**Experimental studies.** This species has been used to study the effects of heavy metals in Pakistan (Shah, 2002). Higher concentrations of copper and zinc caused lethargy and loss of equilibrium.

**Conservation.** This species is widely distributed in various basins in southeastern Iran and neighbouring areas and does not appear to under any threat. Listed as of Least Concern by the IUCN (2015).

**Sources.** Type material:- See above and note reservations on type status of some, *Cirrhina afghana* (BM(NH) 1886.9.21:150-154, BM(NH) 1886.9.21:155-159), *Cirrhina afghana* var. *nikolskii* (ZISP 11709), *Cyprinion kirmanense* (ZISP 11712), *Scaphiodon irregularis* (BM(NH) 1889.2.1:380-384), *Scaphiodon macmahoni* (BM(NH) 1905.11.29:27), *Scaphiodon microphthalmus* (NMW 55897), *Scaphiodon muscatensis* (BM(NH) 1885.11.7:35-40, BM(NH) 1887.11.11:289-291), *Scaphiodon watsoni* (BM(NH) 1889.2.1.370-379, FMNH 2303, NMW 51671, NMW 51672 and NMW 51673, ZMB 11042, ZISP 8278 and ZISP 8279) and *Scaphiodon watsoni* var. *belense* (NMW 19833).

Iranian material:- CMNFI 1979-0138, 49, 17.6-66.8 mm standard length, Fars-Hormozgan border, stream in Rasul River drainage (ca. 27º32'N, ca. 54º58'30"E); CMNFI 1979-0141, 3, 28.7-50.7 mm standard length, Hormozgan, Rud-e Kul at road bridge (27º17'30"N, 56º03'30"E); CMNFI 1979-0143, 22, 19.7-30.8 mm standard length, Hormozgan, marsh in Hasan Langi River drainage (27º21'N, 56º50'30"E); CMNFI 1979-0144, 76, 11.6-50.4 mm standard length, Hormozgan, Minab River at Minab (27º09'30"N, 57º04'E); CMNFI 1979-0145, 139, 9.0-41.7 mm standard length, Hormozgan, Geru River south of Minab (26º55'N, 57º01'30"E); CMNFI 1979-0149, 54, 14.7-93.8 mm standard length, Hormozgan, stream north

of Bandar-e Abbas (27º36'N, 56º14'E); CMNFI 1979-0150, 34, 43.8-101.6 mm standard length, Hormozgan, stream at Gohreh (27º45'N, 56º05'E); CMNFI 1979-0152, 10, 29.7-62.7 mm standard length, Hormozgan, Shur River drainage (28º09'N, 55º43'E); CMNFI 1979-0153, 31, 24.5-84.7 mm standard length, Fars, qanat stream and pool at Qaleh-ye Biabani (28º31'N, 54º53'E); CMNFI 1979-0154B, 49, 28.4-65.4 mm standard length, Fars, stream channels at Koorsiah (28º45'30"N, 54º24'E); CMNFI 1979-0155, 26, 24.9-79.7 mm standard length, Fars, spring at Gavanoo (28º47'N, 54º22'E); CMNFI 1979-0156, 12, 29.7-56.0 mm standard length, Fars, qanat in Rashidabad (28º47'N, 54º18'E); CMNFI 1979-0167, 25, 21.5-56.9 mm standard length, Kerman, qanat at Bam (29º06'N, 58º20'E); CMNFI 1979-0168, 50, 25.7-93.8 mm standard length, Kerman, qanat at Shahabad (29º07'N, 58º16'E); CMNFI 1979-0173, 15, 26.5-84.0 mm standard length, Hormozgan, qanat at Hajjiabad (28º19'N, 55º54'E); CMNFI 1979-0176, 1, 33.1 mm standard length, Hormozgan, Sarzeh River (27º30'30"N, 56º15'30"E); CMNFI 1979-0180, 5, 21.3-71.5 mm standard length, Hormozgan, stream 3 km east of Essin (27º19'N, 56º17'30"E); CMNFI 1979-0181, 19, 22.4-43.0 mm standard length, Hormozgan, Kul River (27º17'30"N, 56º03'30"E); CMNFI 1979-0183, 14, 19.5-65.1 mm standard length, Hormozgan, stream in Rasul River drainage (27º11'30"N, 55º42'E); CMNFI 1979-0185, 4, 21.1-24.5 mm standard length, Hormozgan, stream in Rasul River drainage (27º06'N, 55º45'E); CMNFI 1979-0186, 11, 33.4-67.1 mm standard length, Hormozgan, stream and pools at Sar Khun (ca. 27º24'30"N, ca. 56º25'E); CMNFI 1979-0187, 54, 18.9-73.6 mm standard length, Hormozgan, stream and pools at Sar Khun (27º23'30"N, 56º26'E); CMNFI 1979-0188, 18, 22.6-55.3 mm standard length, Hormozgan, jube at Gohreh (27º45'N, 56º05'E); CMNFI 1979-0189, 20, 16.6-49.8 mm standard length, Hormozgan, jube and pool on road to Darab (27º08'30"N, 55º42'E); CMNFI 1979-0190, 44, 27.7-83.3 mm standard length, Fars-Hormozgan border, spring and pool at Galah Tuyeh (ca. 28º32'N, ca. 55º14'E); CMNFI 1979-0191, 35, 36.6-86.5 mm standard length, Fars, stream 10 km east of Furg (ca. 28º16'N, ca. 55º18'E); CMNFI 1979-0219, 19, 19.1-33.0 mm standard length, Kerman, jube 14 km west of Jiroft (28º37'N, 57º41'E); CMNFI 1979-0220, 4, 28.0-65.5 mm standard length, Kerman, jube 2 km south of Jiroft (28º39'N, 57º43'E); CMNFI 1979-0309, 2, 101.2-108.5 mm standard length, Kerman, Fahraj River at Azizabad (28º57'N, 58º42'E); CMNFI 1979-0310, 1, 74.4 mm standard length, Baluchestan, qanat at Bazman (27º49'N, 60º12'E); CMNFI 1979-0311, 10, 18.1-49.1 mm standard length, Baluchestan, Bampur River at Malakabad (27º11'N, 60º27'E); CMNFI 1979-0312, 39, 13.5-43.4 mm standard length, Baluchestan, dam on Bampur River (27º11'N, 60º36'E); CMNFI 1979-0313, 68, 10.4-99.3 mm standard length, Baluchestan, Bampur River at Bangharabad (27º20'N, 60º46'E); CMNFI 1979-0314, 10, 25.5-118.4 mm standard length, Baluchestan, qanat at Karvandar (27º50'N, 60º46'E); CMNFI 1979-0315, 71, 9.8-63.5 mm standard length, Baluchestan, Bampur River 2 km north of Karvandar (27º51'N, 60º46'E); CMNFI 1979-0316, 22, 14.5-69.8 mm standard length, Baluchestan, stream in Sarbaz River drainage (26º48'N, 61º02'E); CMNFI 1979-0317, 11, 16.5-118.6 mm standard length, Baluchestan, Sarbaz River at Bondan (26º35'N, 61º13'E); CMNFI 1979-0318, 11, 13.8-110.4 mm standard length, Baluchestan, Sarbaz River at Huvar (26º09'N, 61º27'E); CMNFI 1979-0323, 6, 21.9-41.4 mm standard length, Baluchestan, Sarbaz River (ca. 26º26'N, ca. 61º16'E); CMNFI 1979-0324, 39, 14.6-60.5 mm standard length, Baluchestan, Bampur River at Sa’idabad (27º11'N, 60º22'E); CMNFI 1979-0325, 7, 18.3-44.6 mm standard length, Baluchestan, qanat at Espakeh (26º51'N, 60º14'E); CMNFI 1979-0326, 10, 20.8-42.2 mm standard length, Baluchestan, stream south of Pip (ca. 26º35'N, ca. 60º02'E); CMNFI 1979-0327, 10, 24.0-62.4 mm standard length, Baluchestan, stream in Geh (= Kahir) River drainage

(26º32'N, 59º57'E); CMNFI 1979-0329, 82, 17.6-47.5 mm standard length, Baluchestan, stream at Zaminbandan (27º02'N, 61º20'E); CMNFI 1979-0331, 25, 13.1-50.3 mm standard length, Baluchestan, qanat in Saravan (27º22'N, 62º20'E); CMNFI 1979-0332, 9, 20.8-33.3 mm standard length, Baluchestan, qanat at Kalapurkan (27º14'N, 62º33'E); CMNFI 1979-0334, 4, 26.3-38.4 mm standard length, Baluchestan, Mashkid River 5 km east of Esfandak (27º04'N, 62º54'E); CMNFI 1979-0335, 2, 66.8-72.2 mm standard length, Baluchestan, qanat at Esfandak (27º07'N, 62º50'E); CMNFI 1979-0338, 17, 14.2-25.4 mm standard length, Baluchestan, Tahlab River drainage 8 km from Mirjaveh (28º58'N, 61º24'E); CMNFI 1979-0339, 24, 24.5-76.9 mm standard length, Baluchestan, Tahlab River drainage 16 km from Mirjaveh (28º56'30"N, 61º21'E); CMNFI 1979-0411, 8, 17.0-24.4 mm standard length, Hormozgan, Minab River (27º24'N, 57º12'E); CMNFI 1979-0412, 22, 22.0-122.2 mm standard length, Hormozgan, spring at Saras (27º30'N, 57º34'E); CMNFI 1979-0415, 4, 14.4-18.2 mm standard length, Hormozgan, stream south of Ab Garm-e Ganow (27º17'30"N, 56º20'E); CMNFI 1979-0416, 2, 40.1-55.9 mm standard length, Hormozgan, Ab Garm-e Ganow (ca. 27º26'N, ca. 56º20'E); CMNFI 1979-0418, 5, 58.2-111.2 mm standard length, Hormozgan, river near Kahkom (28º09'N, 55º43'E); CMNFI 2007-0031, 12, 22.4-44.4 mm standard length, Baluchestan, headwater of Bampur River (27º51'N, 60º46'E); CMNFI 2007-0033, 15, 26.3-67.2 mm standard length, Baluchestan, Rusgay qanat in Iranshahr (27º13'N, 60º41'E); CMNFI 2007-0034, 3, 43.9-58.0 mm standard length, Baluchestan, headwater stream on road to Zaboli (ca. 26º58'N, ca. 61º27'E); CMNFI 2007-0036, 8, 17.5-69.3 mm standard length, Baluchestan, qanat at Bazman (27º49'N, 60º12'E); CMNFI 2007-0037, 7, 62.4-166.3 mm standard length, Kerman, Hosseinabad and Gamatabad qanats at Bam (29º06'N, 58º21'E); CMNFI 2007-0038, 9, 62.8-101.2 mm standard length, Kerman, Mehtiabad qanat at Bam (29º06'N, 58º21'E); CMNFI 2007-0049, 11, 45.7-69.0 mm standard length, Hormozgan, ditches in upper Kul River basin at Hajjiabad (ca. 28º19'N, ca. 55º55'E); CMNFI 2007-0050, 4, 61.2-92.4 mm standard length, Hormozgan, ditches in upper Kul River basin at Hajjiabad (ca. 28º19'N, ca. 55º55'E); CMNFI 2007-0051, 7, 54.6-84.3 mm standard length, Hormozgan, upper Kul River basin at Hajjiabad (28º19'N, 55º55'E); CMNFI 2007-0052, 2, 70.7-92.3 mm standard length, Hormozgan, ditch at Qotbabad (27º46'N, 56º06'E); CMNFI 2007-0055, 15, 24.5-75.3 mm standard length, Hormozgan, headwater stream in Minab River basin (ca. 27º47'N, ca. 57º12'E); CMNFI 2007-0056, 14, 30.2-70.4 mm standard length, Kerman, qanat at Kahnuj (27º58'N, 57º45'E); CMNFI 2007-0059, 9, 35.6-72.7 mm standard length, Fars, Cheshmeh Barashk (ca. 27º24'N, ca. 54º06'E); CMNFI 2007-0060, 3, 56.2-93.7 mm standard length, Fars, Cheshmeh Ab-e Shirin near Lar (ca. 27º41'N, ca. 54º17'E); CMNFI 2008-0140, 1, 67.0 mm standard length, Hormozgan, Hasan Langi River (no other locality data); CMNFI 2008-0267, 3, 28.7-35.1 mm standard length, Fars, Lar (no other locality data); CMNFI 2008-0278, 3, 48.7-56.0 mm standard length, Kerman, Bam and Kahnuj qanat (29º06'28"N, 58º21'43"E); BM(NH) 1883.8.2:4-9, 5, 42.4-114.9 mm standard length, Baluchestan, Jalq (27º36'N, 62º42'E); BM(NH) 1883.8.2:20-25, 6, 23.1-85.2 mm standard length, Baluchestan, Sib near Dizak (27º15'N, 62º05'E); NMW uncatalogued, 19, 18.1-52.9 mm standard length, Hormozgan, Ab Garm-e Ganow (ca. 27º26'N, ca. 56º20'E).

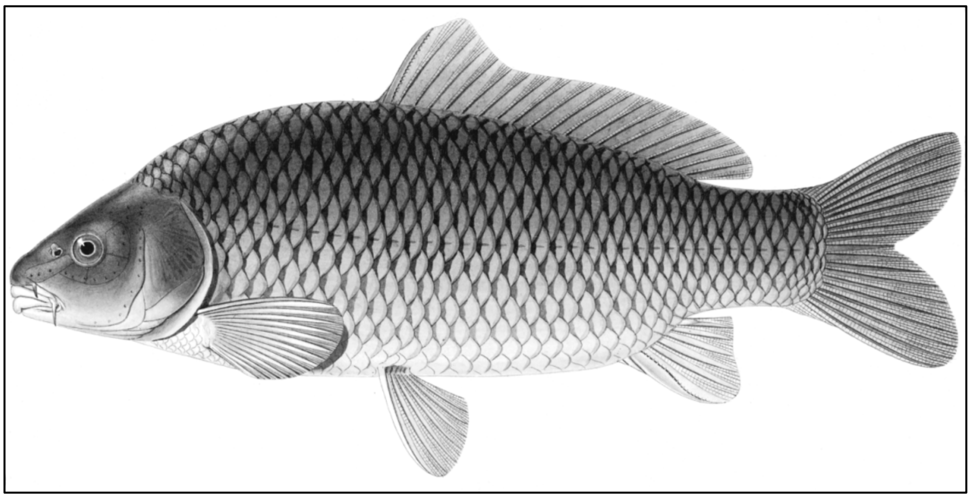
Comparative material:- CAS 28722, 1, 117.4 mm standard length, India, Punjab, Salt Range, Katas Nallah (no other locality data); CMNFI 2008-0051, 1, 111.5 mm standard length, Afghanistan, Helmand, Tshah Ankhir (ca. 31º00'N, ca. 64º00'E).

## **Genus *Cyprinus***
Linnaeus, 1758

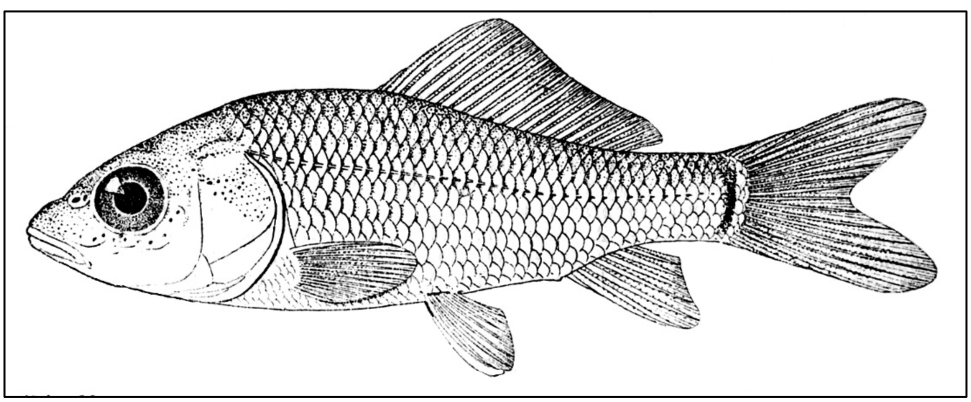
The carp genus is found in Europe and Asia and comprises about 24 species of which one has been widely introduced as a food fish.

This genus is characterised by a compressed but heavy body, large size, rounded snout, two pairs of barbels, large molar pharyngeal teeth in three rows, a very long dorsal fin with the last unbranched ray spine-like and serrated, the anal fin short but with the last unbranched ray spine-like and serrated, the gut is moderately long, and the dorsal and lateral skull bones are sculptured.

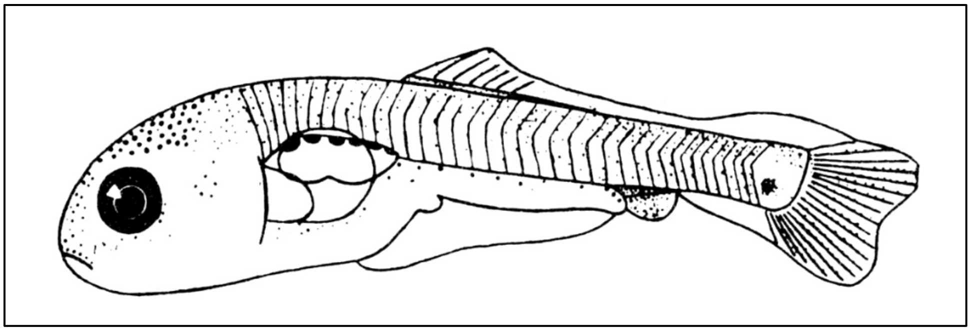
### ***Cyprinus carpio***
Linnaeus, 1758



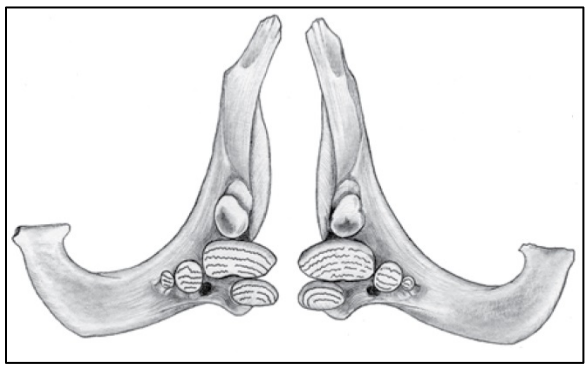
*Cyprinus carpio*, 66.5 cm total length, Russia, Amur River at Khabarovsk, after Berg (1948-1949).



*Cyprinus carpio* fry, 29 mm, Kazakhstan, Ural River delta, after Shukolyukov (1932).

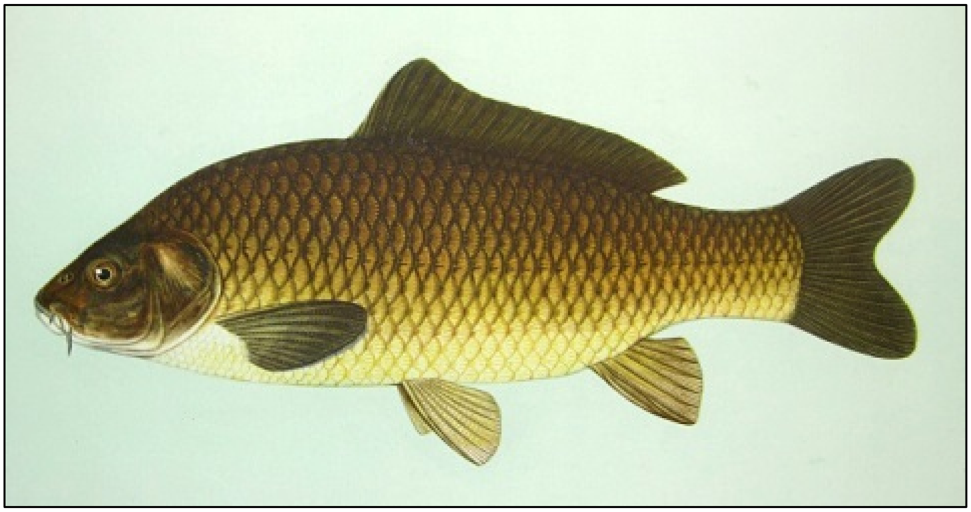


*Cyprinus carpio* fry, 10.1 mm, age two weeks,
Russia, Volga River delta, after Kazanskii in Berg (1948-1949).



*Cyprinus carpio*, 120.0 mm standard length,
pharyngeal teeth (1,1,3-3,1,1)
(CC0, U.S. Geological Survey).

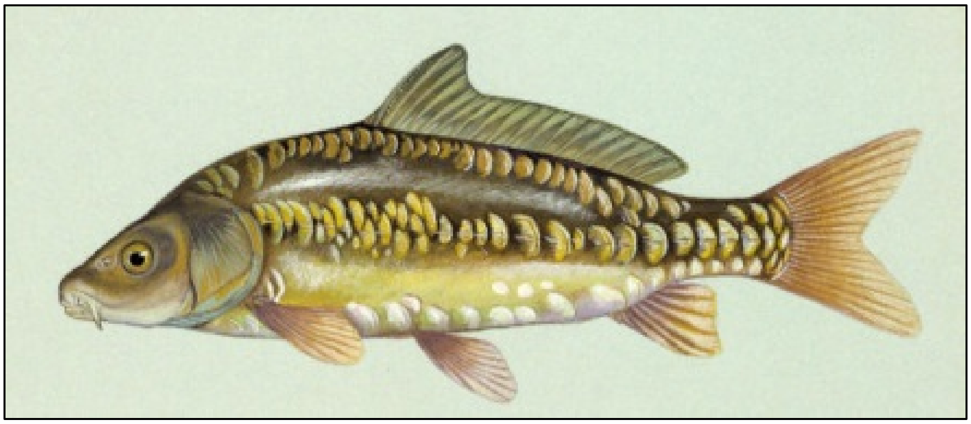
*Cyprinus carpio*, mouth, Brian W. Coad.



*Cyprinus carpio*
(CC0, NOAA Photo Library, N. N. Kondakov).

*Cyprinus carpio*, 370.0 mm, 1.1 kg, *c*aught on sweet corn bait fished on bottom, Gilan, Anzali Talab near Abkenar Village, 15 June 2012, Sarang Nouripanah.

*Cyprinus carpio*
(CC0, U.S. Fish and Wildlife Service, Duane Raver).



*Cyprinus carpio*, mirror carp
(CC0, U.S. Fish and Wildlife Service, Duane Raver).

*Cyprinus carpio*, koi in Japanese garden at Oleško, Czechia
(cropped, CC BY-SA 4.0, Mojmir Churavy).

**Common names.** Kapur, kapoor and kopur (in Gilaki, meaning carp), kapur-e ainehi (= mirror carp), kapur-e ma'mouli or mar'mulleh or ma'muli or maamoli (= common carp)), rashti or kapur-e Rashti in Khuzestan (because their origin was Rasht on the Caspian Sea), mahi-ye gul (= flower fish, meaning in this sense a good fish).

[Carp or carp shaeeh, samti (meaning helicopter - used in the Iraqi marshes from a supposed resemblance in shape), all in Arabic; caki in Azerbaijan; geitan-tsatsan or dliter, both in Armenia; aseel, karpoor, yacarpee or yakoobee, zaghara mahi (Ahmadzai, 2017; Currie, 2006), in Afghanistan; sazan for wild and karp for cultured carp in Russian (Berg, 1948-1949); Adi sazan and Sazan (a local name in eastern Turkey) in Turkish (Kaya *et al.*, 2016, 2020); common carp, European carp, German carp, wild carp, wild common carp; mirror carp, leather carp, line carp, naked carp (last four referring to scalation), koi (aquarium varieties)].

**Systematics.** *Cyprinus Carpio* was originally described from Europe. *Cyprinus carpio* var. *caspicus* Walbaum, 1792 was described from the mouth of the Volga and Don rivers but is

infrasubspecific and the name has not been used in Iran nor has *Cyprinus carpio fluviatilis* Pravdin, 1945 described from floodplain lakes of the Volga River near Saratov.

Berg (1948-1949) summarised data on fish (54 males, 56 females) from the Gulf of Murdab (= Anzali Wetland) which differed from carp in the sea (42 males, 65 females) in a greater length of head, snout, eye, postorbital region and interorbital width and shorter predorsal and preanal distances, shorter dorsal, anal pectoral and caudal fins and a lower anal fin. Mousavi Gel Sefid *et al*. (2007) gave som**e** morphometric and meristic characters of fish from the Anzali Lagoon. Ghelichpour (2010) and Ghelichpour *et al*. (2013) found great allelic richness and gene flow in Gomishan Bay and Gorgan River populations, the most important habitats for this carp in the Iranian Caspian Sea. Ghelichpour *et al*. (2011) examined fish from the Qarasu (= Qareh Su) and Anzali regions of the Iranian Caspian shore using microsatellite markers and found two different populations. Amirjanati *et al*. (2013) found genetically distinct populations in the Anzali Wetland and Gorgan River estuary using microsatellite markers. Fallahbagheri *et al*. (2013a) found that their genetic analysis of Anzali fish indicated two different populations there Siahkeshim Protected Area, and Abkenar + Selke Wild Refuge + Sorkhankol Wild Refuge + estuary. Fallahbagheri *et al*. (2013b), using the mtDNA control region, found a low level of genetic difference between two wetland and one estuarine wild population in the southwest Caspian Sea. Laloei *et al*. (2013) used microsatellite loci to analyse eight populations from the Iranian Caspian Sea basin and found a low level of population differentiation, although the Tajan River population was not closely related to the rest. There was evidence of a common ancestor for this carp from the southern Caspian Sea basin. Laloei *et al*. (2015) used 10 microsatellite loci and found significant genetic divergence between fish in the southern Caspian Sea with at least three groups and with the highest genetic distance between fish from Golestan and Mazandaran. Sadat Hosseyni *et al*. (2017) examined microsatellite diversity on the Golestan coast (Gorgan Gulf, Gomishan Wetland and Qarasu (= Qareh Su) River), finding the samples belonged to populations. Ahmadi *et al*. (2018) used eight microsatellite loci to compare wild (Gorgan and Qareh Su rivers) and farmed fish in the southeast Caspian Sea basin and found genetic diversity was at a proper level and there were no significant differences between wild and hatchery fish. However, farming of fish here started only about 23 years previously and even the slightly lower genetic diversity observed in the hatchery fish should not be ignored and broodstock strategies should be used to promote the observed diversity. Mousavi-Sabet *et al*. (2018b) compared 50 wild carp from the Anzali Wetland with 50 hatchery fish for 78 distance measurements and found morphological separation in 62 measurements such as head shape, pre-dorsal, pre-pelvic and pre-anal distances, caudal peduncle depth, dorsal fin and pelvic fin origins, body depth and caudal fin origin. Jafari *et al*. (2019) examined 74 fish from Anzali, Gomishan and Miankaleh and was able to distinguish them morphometrically as three stocks, head height (presumably head depth) being the most important feature. Andarz *et al*. (2020) used 10 microsatellite markers and found significant differences between fish from Gilan and Mazanderan in number of alleles and genetic diversity. Jafari *et al*. (2021) established a relationhip between morphology and environmental variables indicating a high level of adaptation in fish from the southern Caspian Sea coast (Gomishan, Miankaleh, Rezvanshahr and the Anzali Wetland). For example, caudal peduncle form had positive correlations with pH, alkalinity, nitrate and nitrogen dioxide.

**Key characters.** This species is easily identified by the long dorsal fin, the spine in both the dorsal and anal fins, and the two pairs of barbels.

**Morphology.** The morphology of this species is very variable as there are farmed and aquarium forms. Wild fish have the following appearance. The body is stout, deep and moderately elongate, being deepest in front of the dorsal fin. The dorsal profile is convex from the dorsal fin to the occiput and the dorsal head profile is more or less straight, often with a fold in front of the nostrils. The back is compressed in front of the dorsal fin. The snout is rounded and the eye is in the anterior half of the head. The caudal peduncle is deep and compressed. Dorsal and lateral cranial bones are sculptured and the operculum has numerous radial streaks. The mouth in adults is inferior to terminal and extends back to the nostril level. The lips and barbels are thick. The anterior barbel extends back to the posterior barbel or falls short and the posterior barbel extends to the eye margin or past it. The dorsal fin origin is slightly or well anterior to the level of the pelvic fin origin. The dorsal spine is moderate in size with small denticles extending short of a flexible tip. The dorsal fin margin is emarginated after its high and rounded origin and then is rounded posteriorly. The dorsal fin end falls short of or almost reaches the caudal fin base. The caudal fin is deeply forked with rounded to almost pointed tips. The anal fin is emarginate, its origin lies under the posterior part of the dorsal fin, and it extends back almost to or well short of the caudal fin base. The anal fin spine is similar to the dorsal fin spine although the denticles may be slightly stronger. The pelvic fin is rounded and remote from the anus. The pectoral fin is rounded and may reach back to the pelvic fin origin or fall short.

Dorsal fin with 2-5 unbranched rays followed by 14-23, usually 18-20, branched rays, anal fin with 2-4, usually 3, unbranched rays followed by 3-7, usually 5, branched rays, pectoral fin branched rays 13-19, usually 15-17, and pelvic fin branched rays 5-9, usually 8. Lateral line scales 26-41, mostly 36-39. Scales may be absent (leather carp), restricted to a few, enlarged scales (mirror carp), or only a mid-lateral row of scales (line carp), in cultivated varieties. Wild common carp are fully scaled. Scale shape is squarish with a shallowly rounded posterior margin, gently rounded dorsal and ventral margins, abrupt but rounded anterior corners, and an anterior margin with a central protrusion indented above and below or with a wavy edge. Individual scales have a central focus, wavy anterior margin, few radii on the anterior and posterior fields in young fish, and medium numbers of radii on fish 12-14 cm standard length. There are numerous fine circuli and the posterior scale field breaks up into tubercular structures. Total gill rakers number 17-29 (some literature counts may be lower arm of arch only and there may be size-related variation too). Rakers touch the second raker below when appressed and have a row of knobs on their medial surface. Pharyngeal teeth are 1,1,3-3,1,1 with variants 1,2,3-3,2,1, 1,2,3-3,1,1, 1,1,1,3-3,1,1, 1,1,3-2,1,1 and 1,3-3,1,1. Posterior major row teeth are large with flattened crowns bearing wavy ridges while more anterior teeth are a rounded knob, or even concave on top of the knob. The gut is elongate with several coils, up to three times as long as the body (Berg, 1948-1949). Total vertebrae number 32-39 (lower counts may not include Weberian vertebrae). This species is a tetraploid (2n = 98-104) (Al-Sabti, 1986; Klinkhardt *et al*., 1995; Arai, 2011).

Saadatfar *et al*. (2008) gave details of the barbel structure. Mohammadian Kalat and Shabanipour (2010) used magnetic resonance imaging to distinguish internal anatomy and Mohammadian-kalat and Shabanipour (2013) the same equipment to study skeletal muscles. Nematollahi *et al*. (2014) used a corrosion cast to detail the gill blood vessels of this fish. Abdullah (2016) described the osteology of the premaxilla, maxilla, lower jaw and operculum. Moshayedi *et al*. (2016) documented the body shape changes shown by var. Sazan carp from the Gorgan River estuary during early development (see above under **Common names** for

explanation of Sazan). Banan Khojasteh *et al*. (2009) detailed the histology and histochemistry of the oesophagus and intestine. Moshayedi *et al*. (2017) studied the histology of the digestive system in var. Sazan carp. Mazaheri Kouhanestani *et al*. (2020) gave a description of the larval stage from southeastern waters of the Caspian Sea. Vakili *et al*. (2020) described the morphological characteristics of otoliths of fish from Fereydun Kenar.

There are morphometric and meristic differences between common carp from the southwestern and southeastern Caspian Sea but these are ecological not taxonomic. Also, carp from the Anzali Talab differ from those in the sea by having a longer head, snout, eye and postorbital region (although of course some of these are redundant), greater interorbital width, shorter predorsal and preanal distances, shorter dorsal, anal, pectoral and caudal fins, and a lower anal fin (A. M. Shukolyukov in Berg (1948-1949)). Yousefian (2004) found carp from the Caspian Sea in Iran had a dominant genotype different from those in a fish farm. Meristics (scales and fin rays) and morphometrics (head length and body width) also differed.

Meristic values for Iranian specimens are:- dorsal fin branched rays 16(1), 17(5), 18(18), 19(16) or 20(10), anal fin branched rays 4(1) or 5(49), pectoral fin branched rays 14(1), 15(7), 16(25), 17(16) or 18(1), pelvic fin branched rays 6(1), 7(6) or 8(43), lateral line scales 34(2), 35(6), 36(10), 37(26) or 38(6), total gill rakers 18(1), 19(-), 20(2), 21(11), 22(11), 23(15), 24(4), 25(4) or 26(2), and total vertebrae 36(1), 37(19), 38(26) or 39(6). Note that these samples may include individuals which are not native but introduced for fish farming from stocks outside Iran.

**Sexual dimorphism.** Females are deeper bodied than males because of their eggs and the distance between the pectoral and pelvic fins and the pelvic and anal fins is greater. Dorsal and anal fins in males are higher, the anal fin is longer at the base, the pectoral fin is longer and the lobes of the caudal fin are longer. This is accounted for by the greater swimming activity of males during spawning (Kuliyev and Agayarova, 1984). Breeding males have fine tubercles on the head, particularly on the anterior operculum and preoperculum and under the eye, above the lateral line and more frequently below it, and on the fin rays.

**Colour.** The colour of this species varies greatly with locality (Berg, 1948-1949). In semi-diadromous common carp from the Kura region of the southwest Caspian Sea, the overall body colour was dark yellow, the flanks being golden-yellow with dark shading, and the back was black. The belly and fins were light yellow and the caudal fin was reddish. Lake populations were darker. There was usually a dark spot at the base of each scale and each scale is fringed with pigment dots. Fins were usually dark with the caudal fin having a reddish tinge. Young fish from Iran are silvery on the flanks (but not as bright as *Carassius auratus*), greyish on the back, silver-pearl on the belly, the iris is silvery with grey above and below, the dorsal fin and upper caudal lobe are pale grey, the lower caudal lobe and anal fin are orange, the pelvic fin is pale orange, and the pectoral fin has only traces of orange. The caudal fin may be yellow-orange with lobe margins red. The freshwater resident form in the Anzali Talab is yellowish, the semi-diadromous form dark. The peritoneum is grey to silvery and may be speckled.

**Size.** Common carp resident in fresh waters are smaller than semi-diadromous carp. In the 1950s in Iran, carp catches were 20-41 cm long (Farid-Pak, No date). Fish up to 1.0 m long are caught in the Caspian basin (A. Abdoli, pers. comm., 1995). Maximum size reaches 1.28 m and 46.1 kg, possibly to 1.5 m and 69.6 kg (Machacek (1983-2012), downloaded 27 July 2012).

**Distribution.** This species has been widely introduced in the Middle East for

aquaculture. Found naturally in Iran in the whole Caspian Sea drainage, it is also widely stocked in the provinces of Gilan, Golestan and Mazandaran (Petr, 1987; Abbasi *et al*., 1999). In the Caspian Sea basin it is reported from the Ahar, Aras, Astara, Atrak, Babol, Behambar, Chalus, Ghotor, Golshan, Gorgan, Haraz, Hashtpar, Kelarud, Masouleh, Neka, Pasikhan, Pir Bazar, Polrud (= Pol-e Rud), Qareh Su, Qezel Owzan, Ramsar, Rasteh, Sefid, Selin Chay, Shah, Shalman, Sheikan, Shirud, Siah Darvishan, Tajan, Talar, Zangbar and Zarrin Gol rivers, the Anzali Talab and the Siahkeshim Protected Region, Boojagh Wetland, Fereydun Kenar International Wetland, Gomishan and Shirinsu wetlands, Shourabil Lake, Gorgan Bay and Miankaleh, Shormast Lagoon, at Bandar Anzali, Astara, Bandar-e Gaz, Bandar-e Torkeman, Chalus, Fereydun Kenar, Hashtpar, Khazarabad Sari, Kiashahr and Rezvanshahr, in the Aliabad, Aras, Arasbaran, Golabar, Golestan, Gorgan, Khoda Afarin, Manjil, Sattarkhan, Taham, Taleghan (= Taleqan) and Voshmgarm dams, the southeast Caspian Sea, southwest Caspian Sea and south-central Caspian Sea; and fish in the Haraz and Polrud (= Pol-e Rud) rivers at least are native (Nümann, 1966; Riazi, 1996; Karimpour, 1998; Kiabi *et al*., 1999; Nasrollahzadeh, 1999; Abdoli, 2000; Abbasi *et al*., 2007; Masoumian, 2007; Darafsh *et al*., 2008; Abdoli and Naderi, 2009; Hajirostamloo, 2009; Ghelichpour, 2010; Soufi *et al*., 2010; Khara *et al*., 2011; Ahmadpour *et al*., 2012; Banan Khojasteh *et al*., 2012; Ghelichpour *et al*., 2013; Adeli, 2014b; Gholizadeh *et al*., 2014; Sobhanardakani and Jafari, 2014b; Sobhan Ardakani and Jafari Seyed, 2014; Manavi and Kiadehy, 2015; Salavatian *et al*., 2016; Zareh Reshquoeeieh *et al*., 2016; Babaei, 2017; Khodaparast *et al*., 2017; Raoufi *et al*., 2018; Naderi Farsani *et al*., 2019; Aazami and Alavi Yeganeh, 2021; Jafari *et al*., 2021).

It is probably native to the Tedzhen River of Turkmenistan (the Hari River in Iran) (Aliev *et al*., 1988). This species is also recorded from the Karakum Canal and Kopetdag Reservoir in Turkmenistan (Shakirova and Sukhanova, 1994; Sal'nikov, 1995) and may eventually reach Iranian waters in the Hari River basin from this source.

This species is also found in all basins on fish farms and as escapees. Mirror carp found in the Shadegan Marshes of Khuzestan are escapees from fish farms, for example, and carp are found throughout Khuzestan Province (not caught in the 1970s by me). Abdoli (2000) recorded this species as present generally in the Dasht-e Kavir, Dasht-e Lut, Kerman-Na'in and Sistan basins. In particular and by no means exhaustively, there are also records from the Esfahan, Hamun-e Jaz Murian, Hamun-e Mashkid, Hari River, Hormuz, Kor River, Lake Urmia, Makran, Namak Lake, Persis, Sistan and Tigris River basins. In the Esfahan basin in the Zayandeh River and Dam, the 15 Khordad Dam and at Lavark and Karaskan (Y. Keivany, *in litt*., 1992; Abdoli, 2000; Ghorbani Chafi, 2000; Jalali *et al*., 2005; Jalali and Barzegar, 2005c; Maaboodi *et al*., 2011; Adeli, 2014b); in the Hamun-e Jaz Murian basin in the Halil River (Abdoli, 2000; Ebrahimi, 2001); in the Hamun-e Mashkid in the Mashkid River basin (Malekzehi *et al*., 2014); in the Hari River basin in the Kashaf River and Doosti and Kardeh dams (Abdoli, 2000; Esmaeili *et al*., 2013; Jouladeh-Roudbar *et al*., 2016); in the Hormuz basin in the Kul and Shur rivers (Abdoli, 2000; Bagheri *et al*., 2010); in the Kor River basin in the Dorudzan Dam and at Band-e Amir on the Kor River, the Shadkam River, and the Kaftar and Kamfirouz lakes and wetlands (A. Alamdari, *in litt*., 1997; M. Hafezieh, *in litt*., 1997; Barzegar and Jalali, 2002; Jalali *et al*., 2005; Teimori *et al*., 2010; Ebrahimi and Taherianfard, 2011a; Rahimi and Tabiee, 2013; Zamanpoore and Yaripour, 2017; Paighambari *et al*., 2020); in the Lake Urmia basin in the Aji (=Talkheh), Ghale (= Qal'eh), Mahabad, Saqqez, Simineh and Zarrineh rivers, Marmisho Lake and the Ardalan, Mahabad, Ghalehchai (= Qal'eh) and Zarrineh dams (Abdi, 1999; www.mondialvet99.com, downloaded 31 May 2000; Abdoli,

2000; Mirhasheminasab and Pazooki, 2003; Abbasi *et al*., 2005; Rasouli *et al*., 2011; Adeli, 2014b; Ghasemi *et al*., 2015; Dadai Ghandi *et al*., 2017; Daghigh Roohi *et al*., 2018; Fathi and Ahmadifard, 2019); in the Makran basin in Bahu Kalat and Sarbaz rivers (escapees from fish farms, A. Mobaraki, pers. comm., June 1999) and the Minab and Rudan rivers; in the Namak Lake basin in the Karaj, Kebar, Qareh Chay and Qom rivers, Sar Cheshmeh Spring, Mehr Dasht Lake and Kebar Dam (*Abzeeyan*, Tehran, 5(5):III, 1994; Abdoli, 2000; Mohaghegh, 2008; Abbasi, 2009; Adeli, 2014b; Mousavi-Sabet, 2019); in the Persis basin in Lake Parishan (or Famur) from nearby fish farms, Dasht-e Arjan, the Dalaki and Helleh rivers, the Haft Barm lakes and the Howba Spring (a hot sulphur spring) in the Mond River drainage (Petr, 1987; Maafi, 1996b; Teimori *et al*., 2010; Adeli, 2014b; Golchin Manshadi *et al*., 2014; Esmaeili *et al*., 2015; Pazira *et al*., 2016; Teimori *et al*., 2017; Golchin Manshadi, 2018); in the Sistan basin in a canal flowing into the Hirmand River, the Hirmand River, the Chahnimeh Reservoirs, the Sistan Dam, Hamun Lake and the Hamun Kushk (Ahmadi and Wossughi, 1988; J. Holčík, *in litt*., 1996; Shamsi *et al*., 2009; Latifi *et al*., 2018); and in the Tigris River basin in the Abshalamzar, Arvand, Bahmanshir, Bashar, Beheshtabad, Chamzarivar, Dez, Eivashan (= Eushan), Gamasiab, Jarrahi, Kahman, Kahnak, Karkheh, Karun, Khersan, Mah, Marbureh, Marun, Qareh Su, Shate Neisan and Sirvan rivers, Zaribar lakes, Choghakor (= Chagha Khur) Lagoon, the Agh-Gol and Bisheh-Dalan wetlands, and the Karkheh and Vahdat (= Qeshlaq) dams (*Abzeeyan*, Tehran, 5(5):III, 1994; Abdoli, 2000; Fadaei Fard *et al*., 2001; Jalali *et al*., 2005; Barzegar and Jalali Jafari, 2006; Sadeghinejade Masouleh, 2008; Abbasi *et al*., 2009; Raissy *et al*., 2010; Ansari and Raissy (2011); Bahrami Kamangar *et al*., 2012a; Bozorgnia *et al*., 2012; Esmaeili *et al*., 2013; Khoshnamvand *et al*., 2013; Adeli, 2014b; Khoshnood, 2014; Mansouri *et al*., 2015; Mirzergar and Kulivand, 2017; Pakzad *et al*., 2017; Majlesi *et al*., 2018; Nasri and Eagderi, 2018; Mortazavi and Hatami Manesh, 2019).

Also found in Chitgar Lake, an artificial water body in northwest Tehran (Bagheri *et al*., 2016; Ramin *et al*., 2016; Abbasi *et al*., 2017; MoradiChafi *et al*., 2018). Adeli (2014b) reported carp from the following localities not all of which can be located accurately, namely the Sheh River, the Abbasabad, Bidvaz (Dasht-e Kavir, North Khorasan), Ekbatan (Namak Lake basin, Hamedan), Golpayegan (Namak Lake basin, Esfahan), Hindu, Kamal and Saleh dams, Lake Imam, and the Baba Ali Gipia and Soldoz wetlands.

**Zoogeography.** The natural distribution of the common carp is supposed to be Asia Minor and the Caspian Sea basin where its origins lie in the late Pliocene. From this area, modern wild common carp spread east and west, perhaps as late as the last postglacial thermal optimum, and latterly aided by man (Balon, 1974, 1995; Van Damme *et al*., 2007). Iranian carp may be a mixture of native and introduced stocks (or species - see Kottelat (1997) - but this remains unresolved). It is probably not now possible to distinguish the native stocks morphologically because of admixtures of farmed stocks. All domestic forms probably originated from native Danube River stocks (Bănărescu, Barus and Peňáz in Bănărescu and Paepke, 2002). Khalili and Amirkolaie (2010) compared fish electrophoretically, meristically and morphologically from the Anzali Lagoon, Qareh Su and Bandar-e Gaz. Morphometric differences between east and west were attributed to a relatively smaller body size in the east and the influence of domestic stocks. Electrophoretic differences, particularly obvious at Anzali, were attributed to the larger number of fish farms in this latter area.

**Habitat.** This species is found in rivers, streams, lakes, dams, lagoons, ponds, marshes, and brackish environments. It favours an abundance of soft vegetation in shallow water, necessary for successful reproduction. Still waters are preferred but they are found in the lower

courses of lowland rivers with moderately flowing water, and occasionally in water exceeding 2 m/sec. They can often be seen basking at the surface or feeding on algae and their dorsal fins break the water surface. Large fish often move into shallows in the afternoon and evening. Common carp also leap from the water but the reason is unknown. They rarely descend below 30 m in lakes and avoid fast water in streams. Carp overwinter in depressions in the lower reaches of rivers in the Caspian basin. There are both freshwater resident populations in the Caspian basin and diadromous (or semi-diadromous) ones, the latter living in brackish water near river mouths and only entering fresh water to spawn. The migration up the Ural River may reach 60 km from the river mouth. Some fish apparently spawn in the brackish waters of shallow coastal areas in the Caspian. Riazi (1996) and Karimpour (1998) reported that this species is both native (resident) to, and migrates to, the Siahkeshim Protected Region of the Anzali Talab. Vazirzadeh and Yelghi (2015) noted that southeastern Caspian Sea entered the Qara Su (= Qareh Su, black or dark water) on the spawning migration in such numbers as to change the colour of the river to black or dark.

Knipovich (1921) reported fish in the Iranian Caspian Sea down to 11.9-12.3 m. Fazli *et al*. (2013, 2014) examined bottom trawls at 2-100 m depths in Iranian waters of the Caspian Sea during 2007-2011 at 57 stations. The maximum catch and average catch-per-unit-effort (CPUE) were 39.0 kg and 0.98 kg/0.5 hr in depths of 2-10 m in spring 2011. The bulk of the stock concentrated in depths <20 m in the eastern region (Amirabad to Hasangholi (= Hasan Kuli)), possibly because of stock enhancement programmes by the Iran Fisheries Organization. Seasonal CPUE averages there were 0.69, 1.08, 0.16 and 0.46 kg/0.5 hr in spring, summer, autumn and winter respectively. Afraei Bandpei *et al*. (2017) examined the complex relationship between this species and such biological parameters as phytoplankton, zooplankton and macrobenthos densities and the fish catch ratio of *Rutilus kutum*, which was similar where this could be due to equal reproduction behaviours, feeding periods and anadromy.

Common carp have a salinity tolerance under experimental conditions of up to 8‰, and for short periods 18.6‰ with acclimation, and this has significance for survival of carp in the Caspian Sea and in waters of southern Iran and Iraq where this species is farmed. Hafezamini and Oryan (2002) and Hafezamini *et al*. (2003) however, found that under experimental conditions, all fish in their study died at 18‰ in less than 12 hours. Basir and Peyghan (2019) found experimentally that carp had a high range of tolerance and adaptation to salinity changes because of rapid changes in chloride cells. Carp eggs hatched in water up to 10‰, with the favourable level being up to 6.6‰ (Al-Hamed, 1971).

Low dissolved oxygen concentrations of 3 mg/l are tolerated and levels as low as 0.5 mg/l could be withstood for 2-3 hours. Normal growth has occurred in fish kept at 35°C. It has been caught at 31°C in the Sefid River estuary on 9 July 1962 (CMNFI 1980-0908).

Hatton *et al*. (2018) listed various mean parameters for this species such as the upper incipient lethal temperature (37.3°C), critical thermal maximum (39.7°C), critical thermal minimum (3°C), optimal growth temperature (26.8°C), final temperature preferendum (30.4°C), optimal spawning temperature (19.5°C), and optimal egg development temperature (22.8°C).

This species was considered to be a dominant species in the Karun River along with *Arabibarbus grypus* (*Iranian Fisheries Research and Training Organization Newsletter*, 17:1, 1997). In Chitgar Lake, Tehran it comprised 23.0% of fish numbers caught by gillnets (Abbasi *et al*., 2017). In the Karkheh River it was the most frequently sampled fish (Khoshnood, 2014).

Introduced to Iraqi waters in 1960 as juveniles, this species rapidly became established (Ahmed and Taher, 1988). *Cyprinus carpio* was caught in large numbers in the Shatt al Arab of Iraq down to the estuary after an increase in the discharge of the Tigris River reduced salinity (N. A. Hussain, *in litt*., 1994).

**Age and growth.** Freshwater residents in the Anzali Talab were slow-growing compared to the semi-diadromous form and were less common. Fish taken in the commercial operations in Iran were 3-7 years old, 31.0-63.0 cm long and weighed 539-3,375 g (Razivi *et al*., 1972). Mousavi Gel Sefid *et al*. (2007) gave some growth equations for fish from the Anzali Lagoon or Talab. Moradinasab *et al*. (2012) found 35 Anzali Wetland fish, 20.7-59.8 cm total length, to have a *b* value in the length-weight relationship of 2.7621, negatively allometric, a relative condition factor of 1.3 and a Fulton's condition factor of 1.34.

Fatemi *et al*. (2009) examined 328 fish, 6.3 to 65.6 cm fork length, from beach seines along the Caspian shore of Iran for 2006-2007. Ten age groups were recorded and the catch was dominated by fish aged 4-5 years old. Growth parameters based on scale readings were $FL_\infty$ = 71.52 cm and K = 0.16 per year for the total population, $FL_\infty$ = 70.54 cm and K = 0.15 per year for males, and $FL_\infty$ = 72.00 cm and K = 0.16 for females. Growth parameters based on length-frequency analyses gave values of $FL_\infty$ = 72.0, 69.3 and 73.0 cm and K = 0.18, 0.15 and 0.18 per year, respectively. The total (Z), natural (M) and fishing (F) mortalities were 0.71, 0.29 and 0.42 per year, respectively, for sexes combined. Exploitation (E) was 0.59 for sexes combined and no further fishing pressure was recommended. Bandany *et al*. (2010) found 11 age groups in fish from beach seines in the southern Caspian Sea. Ghasemi (2010) examined fish from the Caspian Sea coast of Iran for 2006-2007, numbering 3,170 specimens, 6.3-65.6 cm fork length, and found *b* values of 2.895, 2.843 and 2.925 for both sexes, males and females respectively, and mean condition factor was close to the ideal at 1.9. The first fork length at maturity was 30 cm for males and 32 cm for females and females predominated at 1:0.66. Length-frequency analysis gave K = 0.17 and $L_\infty$ = 68.04, age-length key gave K = 0.15 and $L_\infty$ = 74.254, and back-calculation gave K = 0.14 and $L_\infty$ = 68.4. Mortality parameters and exploitation rate values were Z = 0.73 per year, M = 0.31 per year, F = 0.42 per year and E = 0.56. Biomass was calculated at 9,640.2 t and MSY (maximum sustainable yield) was estimated at 2,374.5 t. The number of carp in the south Caspian Sea was estimated at 24 million in 2006-7. Fazli (2011) examined catches in the southern Caspian Sea in 2006-2010 and found *Rutilus kutum*, the golden mullet, *Chelon auratus* and carp predominated in the composition of bony fishes, representing 61.3, 29.6 and 7.6% of the total catch. The average fork length was 36.7 cm and weight was 977.0 g for carp. The value of *b* was 2.89, indicating negative allometric growth. The maximum age was 12 years. The sex ratio showed that females were dominant. The von Bertalanffy growth equation was $L_t = 60.5\ (1\text{-}e^{(-0.19(t+0.65)})$. Moradinasab *et al*. (2012) gave a *b* value of 2.8449 for 2,090 fish, 22.7-72.4 cm total length, from beach seine fisheries of the southern Caspian Sea along with a mean relative condition of 1.029 and a mean relative weight of 1.594. Amouei *et al*. (2013) demonstrated that otolith length and weight were good indicators of fish body weight and fork length in beach seine captures based on 160 fish, 20.0-32.0 cm total length, from the southern Caspian Sea. Maximum age was $6^+$ years and length-weight relationship was $W = 0.006TL^{3.232}$. Mohammad Nejad Shamoushaki *et al*. (2013) analysed the catch from 1999 to 2008 in Golestan Province from 20 active seine cooperatives. The catch in the west (Miankaleh) was less than that in the east (Gomishan). Catches declined over the period studied and the catch ratio was carp>mullet>kutum>roach at 39.23, 33.76, 26.54 and 0.47%. Sedaghat *et al*. (2013) studied

604 fish, 23.0 to 50.35 cm fork length, from Iranian Caspian Sea waters finding fish up to 8 years with the four-year-olds most frequent (44.2%). Mean condition factor was 1.83 and growth was isometric ($W = 0.025FL^{2.901}$). Yeganeh *et al*. (2013) compared 85 wild and farmed carp finding a higher condition factor in farmed fish but no difference in gonadosomatic index and growth was isometric in both. Yelghi *et al*. (2014) found 460 Gorgan River estuary fish had a mean length and weight of 466.7 mm and 1,494.4 g, and 430.04 mm and 1,105.62 g, for females and males respectively, mean condition values of 1.07 for females and 1.55 for males, the dominant age group was $5^+$ years and $6^+$ respectively, growth was positive allometric (*b* = 3.025) and negative allometric (*b* = 2.92) and von Bertalanffy growth equations were $L_t = 1054(1-e^{-0.11(t+0.041)})$ and $L_t = 901(1-e^{-0.12(t+0.402)})$. Aazami *et al*. (2015b) gave a *b* value of 3.21 for 28 fish, 5.88-36.97 cm total length, from the Tajan River. Moradinasab *et al*. (2015) examined brood stocks from the sea in Gilan and found females were 3-11 years old and 25.7-62.2 cm long while males were 2-9 years and 22.6-58.3 cm. Growth was negatively allometric for both sexes. von Bertalanffy growth parameters were $L_\infty$ = 725.66 mm, K = 0.12 $yr^{-1}$ and $t_0$ = -0.09 $yr^{-1}$ for males and $L_\infty$ = 831.27 mm, K = 0.09 $yr^{-1}$ and $t_0$ = -0.15 $yr^{-1}$ for females. $T_{max}$ in males was 24 years and 28 years in females and $W_\infty$ was estimated at 6.77 kg for males and 8.68 kg for females. Vazirzadeh and Yelghi (2015) examined 1,250 fish from the southeastern Caspian Sea taken during the 2009-2010 fishing season. Mean total lengths and weights measured 26.2-72.6 cm and 314-3,733 g, von Bertalanffy parameters for both sexes were K = 0.24 $year^{-1}$, $L_\infty$ = 68.13 cm, and life span reached 12 years, dominated by four-year-old fish. Bandani (2016) examined samples taken from beach seine catches and at fish markets. The age composition was 1 to 16 years and most of the catch was in the length range of 31 to 39 cm. Growth parameters were $L_\infty$ = 70.78 cm and K = 1.24/year, total mortality, natural mortality rate, fishing mortality and growth performance index were 1.5/year, 0.5/year, 1.24 and 2.85, respectively. The biomass and maximum sustainable yield were estimated at 1,628.7 t and 88.06 t. Bandani *et al*. (2017) examined 328 fish from the southeastern Caspian Sea and found 11 age groups with males 9.9-56.3 cm and females 6.3-65.6 cm long. Bandani *et al*. (2018) gave growth and mortality parameters for the southern Caspian Sea but there is confusion in values between Farsi and English abstracts.

Paighambari *et al*. (2020) gave a *b* value of 2.89 for 99 fish (21.2-66.1 cm total length) from the Dorudzan Dam, Fars.

Hashemi *et al*. (2014) examined 940 fish, 11.0-49.5 cm total length, from five stations in the Shadegan Wetland or Marsh and found population dynamic parameters as follows:- $L_\infty$ = 53.7 cm, K = 0.36 $yr^{-1}$, $t_0$ = -0.2, growth performance index (Φ’) = 3.01, total mortality (Z) = 1.44, natural mortality (M) = 0.66 and fishing mortality (F) = 0.78, relative yield per recruitment (Y’/R) = 0.02, relative biomass per recruitment (B’/R) = 0.3, exploitation ratio maximum sustainable yield ($E_{max}$) = 0.43, precautionary average target ($F_{opt}$) = 0.51 $yr^{-1}$, and limit ($F_{limit}$) = 0.67 $yr^{-1}$. Exploitation of this stock was more than the optimum level and it was recommended that no increase in fishing level should be made in this area. Hashemi *et al*. (2017) collected 1,401 fish from five stations in the Shadegan Wetland and found mean lengths and weights for males and females were 200 mm and 207 mm and 116 g and 162 g, the length weight relationships were $W = 0.0004L^{2.6}$ for males and $W = 0.00003L^{2.89}$ for females, von Bertalanffy growth parameters for male, female and total fish were $L_\infty$ = 483, 514 and 514 (presumably mm), K = 0.49, 0.31 and 0.36, $t_0$ = -0.15, -0.5 and -0.2, total mortality (Z) = 1.51, 1.41 and 1.44, natural mortality (M) = 0.83, 0.61 and 0.66 and fishing mortality (F) = 0.67, 0.53 and 0.83. The species was classed as moderately vulnerable.

Females were larger and matured a year later than males in the Caspian Sea generally. Sexual maturity was attained in the second year of life and, in a few individuals, even by the end of the first year, in the southeastern Caspian Sea; but in the southwestern Caspian Sea this occurred in the third and fourth years (Kuliyev and Agayarova, 1984). Resident carp in Dagestan matured in their third year at about 30 cm and had an average life span of 6 years whereas the semi-anadromous or semi-diadromous form matured in its fourth year at 35-36 cm and had an average life span of 8 years (Shikhshabekov, 1969). Growth was faster in the Kura River of Azerbaijan than in other populations in the Caspian but maturity was later at age 4 or more usually at 5 years.

Ahmed and Taher (1989) examined the growth of $0^+$ carp in Hawr al Hammar, Iraq and found the length-weight relationship to be $W = 0.00004627\ L^{2.8022}$ and derived the growth equation $L_t = 189.87\ (1\text{-}e^{-0.0158\ (t\ +\ 25.662)})$. Length at the end of the first year of life was relatively larger than for other parts of the world, indicating a successful introduction of this exotic. Al-Nasiri and Dawood (1991) found the smallest mature male was 182 mm and the smallest female was 184 mm in Hawr al Hammar, with sexual maturity achieved in the first year of life. Maximum life span was $8^+$ years. This species was stocked in the Dukan and Derbendikhan dams of Iraq in the 1960s where fish up to 3 years of age were reported by Ciepielewski *et al*. (2001). Decreasing growth rates indicated conditions were not too favourable although growth in the first 2 years was comparable with that in lakes of central Iraq. The condition coefficient (K) was higher among smaller fish, e.g., fish from Dukan at 230 g had a K of 2.32, at 1 kg K was 1.75. Epler *et al*. (2001) found the oldest age groups in Iraqi lakes to be $5^+$ in Lake Habbaniyah and $3^+$ in Lake Razzazah. The mean condition factor was 1.47 for Lake Habbaniyah and 1.5 for Lake Razzazah.

In Sariyar Dam near Ankara in central Anatolia, ages ranged from 0 to 18 years (Ekmekci, 1996). In their first year, fish had an average fork length of 103 mm and a weight of 24 g, in 5 years they averaged 357 mm and 822 g, and in 10 years 580 mm and 3,365 g. In Gölhisar Lake by contrast, a small water body in western Turkey, age composition was from 1 to 6 years and fish attained a maximum of 494 mm and 1,922 g (Alp and Balik, 2000). Vilizzi *et al*. (2015) summarised growth of this species in Anatolian Turkey with native and invasive populations world-wide. Growth was slower in cold and arid climates or hot and dry summers in contrast to temperate climes. Also, it was slower in mirror relative to scaled types, males to females, but not waterbody types (dams, lakes, water courses). Growth performance and mortality decreased with increasing altitude and decreasing temperature, a trade-off between growth and reproduction. Growth was lower in Anatolia than in its native Eurasian habitat and in invasive North American populations, attributed to lower resilience of the widespread mirror variety and limited spawning habitat in man-made water bodies.

Maximum life span for this species is reported as 47 years for domestic fish.

**Food.** Food is derived from browsing on the substrate at all hours, if the temperature is favourable. Browsing muddies the water and can inhibit other species and uproot plants. Mouthfuls of bottom ooze are taken up, spat out and the food items selected. These include aquatic insects, crustaceans, worms and molluscs, and more rarely, fish. Plant material is ground up by the molar pharyngeal teeth and includes algae, seeds, wild rice, leaves and various aquatic plants. Organic sewage is also eaten. Some surface feeding on algal mats or insects will also occur. Feeding almost completely stops in winter and the fish go into a form of hibernation.

Matinfar *et al*. (2010) examined 180 fish from the Gomishan area of Golestan Province

and found a relative gut length of 1.67 for fish $2^+$ to 10 years, gut fullness index varied between seasons, condition factor (K) was 1.39 indicating good nutrition, and gut contents were dominated by Polychaeta, Bivalvia and plant remains, with other food items being Oligochaeta, Gastropoda, Ostracoda, Amphipoda, *Balanus*, Cumacea, Foraminifera, gobiid fish remains, invertebrate eggs and crabs. Fazli (2011) found that molluscs dominated in the diet of fish in the southern Caspian Sea. Ghane (2013) and Ghane *et al*. (2018) found the exotic freshwater prawn, *Macrobrachium nipponense*, as a significant food item in carp 1-8 years old from the Anzali Wetland, comprising 56% of main food items when included with crabs and molluscs. Bandani *et al*. (2017) examined 328 fish from the southeastern Caspian Sea but only 66 had food in their stomachs. The commonest food was molluscs in all seasons followed by annelids in spring and plants in fall and winter. This species was an opportunistic and flexible feeder and diet was based on abundance and accessibility of foods. MoradiChafi *et al*. (2018) found fish aged 1-8 years (mean 4.04 years) and 10.2-85.0 cm total length (mean 41.4 cm) from the Chitgar Lake, Tehran had an average condition factor, gut length and feeding intensity of 1.58, 1.75 and 127.6, respectively. Fish in September were omnivorous and feeding intensity was not good. The fish fed on a medium spectrum of benthos such as Chironomidae (larvae and pupae), Tubificidae, Gastropoda, palaemonid shrimps, fish, algae, periphyton and particles of bread. The most numerous food items were Chironomidae with 61.1% and Gastropoda with 24.7%, respectively. Naderi Jolodar *et al*. (2019) found fish at Goharbaran, Mazandaran fed mostly on detritus, followed by bivalves (*Abra ovata*), gastropods, oligochaetes, polychaetes (*Nereis*), fish eggs and filamentous algae.

Feeding in the Hawr al Hammar, Iraq was related to temperature, the peak intensity being July and the minimum in January, and with peak activity in September and minimum in January. Feeding occurred year-round and smaller fish (<20.0 cm) had a highest feeding activity in spring while adults had this in summer (Hussein *et al*., 2000a). Hussein *et al*. (2000b, 2000c) studied dietary overlap between this species and three native carps in the Hawr al Hammar. Overlap with *Barbus* (= *Mesopotamichthys*) *sharpeyi* was the weakest as this species is an herbivore but small *C. luteus* (<20.0 cm) and *L. xanthopterus* showed strong overlaps. This overlap may explain the decline in some native carps. In a study of the recovering Hawr al Hammar, diet was 25.45% algae, 18.18% snails, 12.73% diatoms, 12.73% copepods and 10.91% insects, with plants, cladocerans and shrimps at less than 10% each, in the Hawr al Hawizeh diet was 27.3% snails, 18.2% insects and 12.1% for algae, plants and cladocerans with fish, diatoms and copepods at less than 10% each, and in the Al Kaba'ish (= Chabaish) Marsh diet was 33.3% algae, 20.4% insects, 11.1% snails, diatoms and plants at 10.2%, with various crustaceans at less than 10% each (Hussain *et al*., 2006). Hussain and Ali (2006) also examined feeding relationships among fishes in the Hawr al Hammar and found this species to be a carnivore, 26.4% of the diet being crustaceans, 12.7% insects and 30.5% molluscs. Dietary overlap of 84% was found between this species and *Barbus* (= *Luciobarbus*) *xanthopterus* but the availability of food resources offset possible competition, contrasting with the conclusions above.

Mangalo and Akbar (1988a, 1988b) studied the food of carp in a farm pond at Al-Latifiyah, Baghdad where zooplankton was the principal diet. Hussein *et al*. (1993) examined diet in the Garma Marshes, Iraq and found crustaceans, molluscs, aquatic plants and seeds, aquatic insects, oligochaetes and fish to be dietary items, selection and numbers varying with carp size and season. Some fish were found to have fed exclusively on only a single, different mollusc species, presumably as opportunity presented. The gill rakers showed an efficient

structure for filtration, indicative of phytoplanktivorous and omnivorous feeding (Salman *et al*., 1994). Al-Shamma'a *et al*. (1996) examined the food of this species in Al Qadisiyah Reservoir, Iraq and found plants, their seeds, molluscs and aquatic insects, all bottom foods. Salman *et al*. (1994) reported a mixture of animal and plant foods, with zooplankton a dominant component of all length groups. The gut is coiled and 3.42 times standard length, indicating omnivory with plant food being important. Ciepielewski *et al*. (2001) found the diet of this species in the Dukan and Derbendikhan dams in Iraq to be mainly algae, copepods and chironomids. Epler *et al*. (2001) gave the diet in Lake Habbaniyah, Iraq as 51.7% plants, 15.7% oligochaetes, 15.2% tendipedids, 7.2% molluscs, 5.2% detritus and 4.1% cladocerans. They also found that where there was significant competition between autochthonous species, as here, carp became another strong competitor for food. Dietary coincidence between carp and *Arabibarbus grypus*, *Carasobarbus luteus* and *Luciobarbus xanthopterus* was 58.5, 54.2 and 68.5% respectively. Mohamed and Abood (2018) found this species was a low specialised feeder in the Shatt al Arab, Iraq and the diet comprised aquatic insects (37.8%), macrophytes (19.0%), snails (17.2%), detritus (9.8%) and fish (7.1%).

**Reproduction.** Under natural conditions generally, males spent more time on the spawning grounds than females and spawned several times. More than seven million eggs up to 1.71 mm in diameter may be present in a female but only about 500 were laid at a time. The spawning behaviour involves stimulation of a female while moving over vegetation and being accompanied by 2-3 males, active movement and spawning being induced by blows from the male(s). The eggs adhere to the vegetation or are lost. Most eggs are shed at night or in the early morning.

Carp have feeding grounds in the coastal waters of the southeastern Caspian Sea and entered the Atrak River in winter to spawn between February and April. Young migrated downstream, this movement ending in July when the river flow was minimal or ceased. When there was no flood, spawning did not occur (Petr, 1987). These wild common carp in the Atrak River had a fecundity range of 16,000 to 543,000 eggs (Bănărescu, Barus and Peňáz in Bănărescu and Paepke, 2002). The resident form was less fecund by about half than the semi-anadromous form (Shikhshabekov, 1969).

In the Anzali Talab a mass spawning run took place in April with spawning in April-May. The first migratory fish were seen as early as January. Shallow weedy areas or the mouths of rivers were used as spawning sites and adhesive eggs were laid on plants. Abbasi *et al*. (2019) examined 100 wild, pre-spawning females from the Anzali Wetland and found 11,312-1,280,460 eggs for batch fecundity, 19,773-1,504,448 eggs for annual fecundity, 39,400-286,500 eggs for relative batch fecundity and 69,400-394,300 eggs/kg body weight for relative annual fecundity. Batch and annual fecundity was correlated with body weight, total length and age. Fish were more fecund than those from the Golestan shore. Abbasi *et al*. (2022) examined 1,023 wild carp caught in the Anzali Wetland monthly from October 2015 until March 2017. The fish showed a body weight range of 54.3-2,264.0 (mean 687.6 g) in adult males (n = 333) and 226.1-5483.0 (mean 856.7 g) in adult females (n = 367) with a significant difference between them. Total length was 161.0-571.0 (mean 369.3 mm) in adult males and 260.0-761.0 (mean 391.3 mm) in adult females with a significant difference between them. Length maturity in 50% females was calculated at 352.0 mm total length. Adult males and females were 3-10 and 3-12 years old respectively, and thus maturity in both sexes was in 3-year-olds. Adult males numbered 1.58 times more than adult females in running ripe to newly fully spent individuals in the spawning season (spring and summer). There were three different

batches of eggs (large, medium and small) in adult female ovaries. The averages of absolute and relative batch fecundity (only large eggs) were estimated at 170,977.6 eggs and 132,400 eggs/kg of body weight, respectively. The carp spawned from late March until October at a water temperature of 13-27°C. Individuals selected only the multiple batch spawning model per spawning period, which accorded with more spawning months and fecundity than other populations in the southern Caspian Sea basin.

Yousefian *et al*. (2009) examined the normative reproduction values and genetic characters for native carp in the Caspian Sea. The average weight of sampled fish was 1,441.6 g and standard length was 50.5 cm. Fertilisation rate was 62-79%, absolute fecundity was 114,347 and relative fecundity 82,007. There were no significant differences in haplotype distribution between areas in the southern Caspian Sea. Bandany *et al*. (2010) found fish from beach seines in the southern Caspian Sea had two peaks in their gonadosomatic ratio, in April and December, the latter much shorter than the first. Fecundity variations were high, from 77,448 to 430,745 eggs. Ghelichi *et al*. (2010) used histology and gonadosomatic indices on fish from the commercial fishery in Golestan and from research organisations to determine that spawning occurred over at least 8 months. The mean absolute fecundity was 143,302 eggs. However, Ghelichi *et al*. (2011) detailed oocyte development from beach seine caught fish in Iran and determined spawning occurred in spring. Fazli (2011) found the spawning season extended from March to August in the southern Caspian Sea. Absolute fecundity was 131,000 eggs. Length at maturity (Lm50%) was 31.6 cm. Enayat Gholampoor and Imanpoor (2012) sampled 90 female broodstock in Gorgan Bay finding stock with a length of 29.5 cm had an hepatic index of 0.43 and a gonadosomatic index of 12.12, stock with a length of 44.5 cm had an hepatic index of 0.32 and a gonadosomatic index of 9.89, maximum and minimum absolute fecundity was156,238 and 52,429 eggs, and relative fecundity was 94,335 and 130,581 eggs/kg. Absolute fecundity increased with fish size but not relative fecundity, and the index of total length could be used as a subtle means of selecting broodstock. Yelghi *et al*. (2014) found 460 Gorgan River estuary fish had a gonadosomatic index of 16.98 with maximum values from the end of April to May and average absolute fecundity was 185,254 eggs. Vazirzadeh and Yelghi (2015) examined 1,250 fish, 26.2-72.6 cm and 314-3,733 g, from the southeastern Caspian Sea where mean fecundity ranged from 33,695 eggs in four-year-old fish to 1,234,567 eggs in 12-year-old fish with a mean of 273,000 eggs. Egg diameters were 0.69-1.53 mm, mean 1.32 mm. Ovarian development was asynchronous and carp spawned over at least six months with peaks in autumn and spring. Some fish were resident to the sea and spawned in coastal waters without a river migration.

Shirali *et al*. (2011) used histology and histometry on broodstock and found a breeding season from April to October in Khuzestan. The climate allowed rapid maturation and the ability to spawn three times in a year.

Resident populations in Dagestan spawned earlier, by about a month, than the semi-anadromous population which spawned in early May (Shikhshabekov, 1969). Spawning time variations were governed by temperature and the most favourable temperature was 18-20°C. Carp ascended the Kura River of Azerbaijan in spring and autumn. The spring run began in mid-March and peaked in April while the weak autumn run lasted from August to mid-October.

Fish in Iraqi ponds grew 25-30 cm in the first year of life and matured in 1-2 years. At 16-26ºC they spawned from late February to late April and again in the autumn (Al-Hamed, 1960). Palm tree fibres were used for egg deposition and eggs hatched in 4-8 days. Al-Nasiri

and Dawood (1991) found a fecundity range of 14,150-1,492,500 eggs in Hawr al Hammar with a mean relative fecundity of 182 eggs/g of body weight, and egg diameters of 0.90-1.02 mm. The gonadosomatic index indicated spawning in March and possibly October-November. Epler *et al*. (2001) studied reproduction in lakes Habbaniyah and Tharthar and found both sexes achieved maturity in the first year of life at 13.5 cm for males and 12.6 cm for females. Spawning occurred in May and fecundity was 186,000-531,000 eggs/kg body mass.

**Parasites and predators.** The carp is a fishery and farmed species in Iran and consequently parasite studies have been carried out for commercial reasons. They are grouped below in five-year intervals. Extensive studies have only been carried out since the year 2000.

Eslami and Anwar (1971) recorded the cestode *Caryophyllaeus fimbriceps* from this species on the Caspian coast of Iran and Mokhayer (1976b) recorded the cestode *Bothriocephalus gowkongensis*, the nematode larva *Anisakis* and the acanthocephalan *Pomphorhynchus perforator*.

Mokhayer (1989) reported metacercariae of the eye fluke, *Diplostomum spathaceum* from this species in Iran, which can cause complete blindness and death in commercially important species.

Jalali and Molnár (1990b) variously recorded the monogeneans *Dactylogyrus anchoratus*, *D. extensus*, *D. sahuensis* and *D. vastator* from common carp on fish farms throughout Iran. Moghainemi and Abbasi (1992) recorded a wide range of parasites from this species in the Hawr al Azim in Khuzestan.

Sattari and Faramarzi (1997b) reported *Caryophyllaeus brachycollis*, *C. fimbriceps* and *C. laticeps* from 38% of carp in the Anzali Lagoon. Akhlagi (1999, 2000) found that high temperatures (up to 32°C) stressed this species and left it open to infection with *Aeromonas hydrophila*. The intestinal helminth *Bothriocephalus gowkongensis* was recorded from this species on fish farms in West Azarbayjan Province (Azarvandi *et al*., 1999). Mousavi and Khosravi (1999; www.mondialvet99.com, downloaded 31 May 2000) found the toxigenic fungi *Aspergillus flavus*, *Alternaria*, *Fusarium* and *Penicillium* on this species and in the pond water at a fish farm in northern Iran. Safari and Khandagi (1999) recorded *Clostridium botulinum* from 3.8% of fresh and smoked samples of this species in Mazandaran Province.

Mortezaei *et al*. (2000) recorded an infection rate of 66% (but only 2 of 3 fish) with the worm *Bothriocephalus opsariichthydis* in Khuzestan marshes. Farahnak (2000a, 2000b) studied Anisakidae from this species in Khuzestan. Akhondzadeh *et al*. (2002) and Akhondzadeh Basti and Zahrae Salehi (2003) showed that the psychotropic pathogen *Listeria monocytogenes* was present in market and fish farm samples. *Listeria* also contaminated fish from Urmia markets for example (Modaresi *et al*., 2011) and this bacterium could cause serious disease in humans with a mortality rate at about 20%. Barzegar and Jalali (2002) reported parasites in this species from Kaftar Lake as *Dactylogyrus anchoratus*, *D. extensus*, *Dermocystidium* sp., *Diplostomum spathaceum*, *Gyrodactylus* sp., *Lernaea cyprinacea* and *Trichodina* sp. Farahnak *et al*. (2002) recorded *Anisakis* sp. and *Contracaecum* sp. from this fish in Khuzestan Province. Masoumian *et al*. (2002) investigated parasites from carp in the Aras and Mahabad dams in northwest Iran and found the protozoan *Goussia carpelli*, also known from carp in the Sefid River. Naem (2002) recorded *Dactylogyrus anchoratus* from fish in the Sefid River. Naem *et al*. (2002) found the following parasites on the gills of this species from the western branch of the Sefid River, the protozoans *Ichthyophthirius multifilis* and *Trichodina* sp., a copepod crustacean *Lernaea* sp., and monogenean trematodes *Dactylogyrus achmerowi* and *D. anchoratum*. Jalali *et al*. (2002) and Jalali and Barzegar (2006) recorded

parasites from this species in Lake Zaribar, namely two species of *Argulus*, *Dactylogyrus extensus*, *Diplostomum spathaceum*, *Gyrodactylus stankovici*, *Lernaea cyprinacea*, *Pseudocapillaria tomentosa* and *Trichodina pediculus*. Mehdipoor *et al*. (2004) reported the monogenean *Dactylogyrus extensus* in Zayandeh River fish.

Araghi Soureh and Jalali Jafari (2005) found *Dactylogyrus extensus* in carp from the Mahabad River of the Lake Urmia basin. Ebrahimzadeh Mousavi *et al*. (2005) isolated the fungus *Branchiomyces* spp. from gill lesions of farmed carp in northern Iran. Branchiomycosis or gill rot is a major problem in commercial fish production. Jalali *et al*. (2005) summarised the occurrence of *Gyrodactylus* species in Iran and recorded *G. cyprini*, *G. elegans*, *G. shulmani*, *G. sprostonae*, *G. stankovici* and *G*. sp. from various localities for the carp. Jalali and Barzegar (2005c) recorded five species of monogeneans in the genus *Dactylogyrus* from both farmed and native *Cyprinus carpio* in Iran. These were *D. achmerovi*, *D. anchoratus*, *D. extensus*, *D. sahuensis* and *D. vastator*. Fry and fingerlings were more sensitive to these parasites and this sensitivity was increased with crowding in ponds. The paper also dealt with gill histopathology and distribution of the parasites in Iran. Khara *et al*. (2006b) recorded the cestode *Caryophyllaeus fimbriceps* from this species in the Boojagh Wetland of the Caspian coast. Masoumian (2007) reported the parasite *Diplozoon megan* from fish in the Aras, Ghotor and Zangbar rivers in West Azarbayjan. Mortezaei *et al*. (2007) found the nematode *Rhabdocona denudata* in fish from Shadegan Marsh, Khuzestan. Pazooki *et al*. (2007) recorded various parasites from localities in West Azarbayjan Province, namely *Digramma* sp., *Argulus foliaceus*, *Diplostomum spathaceum* and *Ligula intestinalis*. Sattari *et al*. (2007) recorded the cestode *Caryophyllaeus fimbriceps,* the digenean *Diplostomum spathaceum* and the monogeneans *Dactylogyrus extensus*, *Gyrodactylus* sp. and *Diplozoon* sp. in this species in the Anzali Wetland of the Caspian shore and also mentioned that *Caryophyllaeus laticeps* is also known from this species in the Iranian Caspian Sea. Azizi *et al*. (2008) determined parasitic infection of common carp from the Zayandeh River Dam finding *Caryophyllaeus fimbriceps* and *Rhabdochona* sp., with variations between dam sites and increasing infection with age. Barzegar *et al*. (2008) recorded eye parasites from this fish including the monogenean *Gyrodactylus stankovici*, the digeneans *Diplostomum spathaceum* and *Tylodelphys clavata,* and the crustacean *Lernaea cyprinacea*. Khara *et al*. (2008) found the eye parasite *Diplostomum spathaceum* in this fish from Boojagh Kiashahr Wetland in Gilan. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Argulus* sp., *Argulus foliaceus*, *Ergasilus sieboldi*, *Lernaea* sp. and *Lernaea cyprinacea* on this species. The tapeworm, *Ligula intestinalis*, which could potentially harm humans, was found in fish from the Sattarkhan Dam, East Azarbayjan (Hajirostamloo, 2009). Safari and Ghafourian (2009) found the human infectious bacteria *Listeria monocytogenes* and *Escherichia coli* in the intestine of fish from a hatchery in Razavi Khorasan, caused perhaps by high pollution and low temperatures. Shamsi *et al*. (2009) found *Dactylogyrus achmerovi*, *D. anchoratus*, *D. extensus*, *D. sahuensis* and *D. vastator* in this species in fish farms, the Sefid River and the Hamun Lake.

Firouzbakhsh and Khosravi (2010) found up to six species of *Aspergillus* fungus on cultivated fish from Mazandaran. Khara *et al*. (2011) listed the monogenean *Dactylogyrus* sp., the digenean *Diplostomum spathaceum*, the cestode *Caryophyllaeus fimbriceps*, the crustacean *Lernaea cyprinacea* and the leech *Piscicola* sp. from this fish in the Boojagh Wetland of the Caspian Sea. Maktabi *et al*. (2011) recorded the incidence of *Listeria* spp. on Khuzestan market fish from fish farms and the frequency was a matter of concern. Rasouli *et al*. (2011) found the crustacean *Argulus foliaceus* on fish from Marmisho Lake west of Urmia. Abedi *et*

*al*. (2012) reported the first epidermal inclusion cyst in a pond specimen of carp. Azadikhah *et al*. (2012) reported *Diplostomum spathaceum*, which could cause serious economic loss in cultured fishes, from 82% of Mahabad Dam fish. Borji *et al*. (2012) found 61% of fish from ponds around Mashhad had parasites, dominated by monogeneans. Parasites in decreasing order of frequency were *Dactylogyrus extensus*, *D. anchoratus*, *Ichthyophthirius multifilis*, *Trichodina nigra*, *Capillaria* spp., *Procaecum* spp., *Argulus foliaceus* and *Lernaea cyprinacea*. Similar results were found by Nematollahi *et al*. (2013). Golchin Manshadi *et al*. (2012) and Golchin Manshadi (2018) found *Dactylogyrus extensus*, *Gyrodactylus* sp., *Ichthyophthirius multifilis* and *Trichodina nigra*, in this species in Lake Parishan, Fars. Raissy *et al*. (2013) reported on a parasitic outbreak of *Lernaea cyprinacea* in the Choghakhor (= Chagha Khur) Lagoon, Chahar Mahall and Bakhtiari Province. Rasouli (2013) found the digenean *Diplostomum spathaceum* in fish from Caspian drainages in West Azarbayjan. This parasite could cause secondary infections as the metacercariae penetrate the skin and eye, lesions, appetite loss, blurry vision, and reduced feeding. Sadeghi Limanjoob *et al*. (2014) found 69% of fish from four fish farms at Shushtar, Khuzestan were infected with *Lernaea cyprinacea*. Seyed Mortezaei (2014) and Mortezaei *et al*. (2014) compared four RNA isolating methods for identification of spring viraemia, a highly contagious rhabdovirus that primarily affects the common carp. Sadeghi Limanjoob *et al*. (2014) examined carp from farms in the Lake Parishan, Fars area and recorded the histopathology and prevalence of gill necrosis while Sadeghi Limanjoob *et al*. (2014a, 2014b) examined the prevalence of bothriocephalosis and ligulosis in fish from Lake Parishan, apparently affected by drought conditions which altered the ecology.

Mirzaei and Khovand (2015) found the crustacean *Argulus foliaceus* on ornamental fish (koi carp) in Kerman and thought it could be a risk factor for natural ecosystems. Rasuli and Pourghasem (2015) examined fish from the Zarrineh River in the Lake Urmia basin and found *Dactylogyrus extensus*, *Ichthyophthirius multifilis* and *Lernaea* sp. Sharifian (2015) noted that lernaeasis (infection with *Lernaea cyprinacea*) was a major problem in farmed and wild common carp in Iran but incidence and density was higher in farms than rice fields, possibly because of pesticide use, in particular diazinon, in the rice fields. Shokri *et al*. (2015) examined fish from earthen ponds in Ghaemshahr (= Qaem Shahr, Mazandaran) and found species of *Trichodina*, *Ichthyophthirius*, *Dactylogyrus* and *Bothriocephalus* (with the highest intensity infection), as well as Nematoda and Acanthocephala. Tarahomi *et al*. (2015) found 69 of 275 fish from four rearing ponds at Shushtar, Khuzestan were infected with *Lernaea* sp. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Neoechinorhynchus rutili* (Mahabad Dam), *Neoechinorhynchus* sp., (Khuzestan), *Pallisentis cholodkowskyi* (Mahabad Dam, Choghakhor (= Chagha Khur) Lagoon, Zayandeh River Dam and 15 Khordad Dam, Esfahan) and *Pomphorhynchus perforator* (Caspian Sea). Daghigh Roohi (2016) recorded *Dactylogyrus extensus* and *Diplozoon* sp. from fish in the Anzali Wetland. Moshaverinia *et al*. (2016) found several *Argulus* species in fish in Mashhad pet stores. Panjvini *et al*. (2016) showed that parasitic infections of farmed fish altered haematology, and an increase in white blood cells may be in relation to a defense mechanism and immunological responses against parasites. Rahmati-Holasoo *et al*. (2016) found mass mortalities in koi from koi herpesvirus in Iran. Rahnama *et al*. (2016) examined 1,000 carp from the Chahnimeh Reservoirs in Sistan for prevalence of *Lernaea* spp., the highest rate being 16.4% in spring, varying with fish size and season, seriously affecting skin and muscle tissues, and being a potentially serious disease for the fish industry. Sayyadzadeh *et al*. (2016) found the anchor worm *Lernaea cyprinacea* in fish

from the Kor River basin where it had also spread to native species, presumably from this introduced species or introduced *Carassius auratus*. Soltani *et al*. (2016) isolated and gave phenotypic and molecular characterisations of motile *Aeromonas* species, the cause of bacterial haemorrhagic septicemia in farmed carp in spring and summer. Torabi *et al*. (2016) developed a PCR test for glycoprotein genes of the koi herpes viral disease which causes gill lesions and kills carp rapidly. Ahmadi *et al*. (2017) examined the morphological, molecular and phylogenetic relationships of monogenean parasites in the genus *Dactylogyrus* on fish from Mashhad. Baes *et al*. (2017) examined koi from 10 ornamental fish centres in Tehran, randomly selected, and found *Lernaea cyprinacea* on 3% and *Argulus* sp. on 2% of fish, with *Trichodina* spp. (14%), *Dactylogyrus* spp. (16%), *Gyrodactylus* spp. (10%) and *Epistylis* sp. (5%). A short-term salt bath (20 g/l for 30 minutes) was used and, because of their low numbers, *Argulus* and *Lernaea* spp. could be removed by forceps. Golchin Manshadi (2017) reported *Dactylogyrus extensus* and *Gyrodactylus* sp. from fish in Lake Parishan, Fars. Yazdanpanah et al. (2018) recorded the monogeneans *Dactylogyrus* spp., *Gyrodactylus* spp. and the crustacean *Lernaea* from farm ponds in Kerman Province. Hosseini Fard *et al*. (2017) found that carp had the second highest percentage (76%) of contaminated fish at Babol, Mazandaran after *Carassius carassius* (probably *C. auratus*) (89.04%) and were susceptible to the *Trichodina* parasite. Other parasites were *Dactylogyrus*, *Gyrodactylus*, *Diplostomum spathaceum*, *Rhabdochona fortunatowi* and nematodes. Khalafiyan *et al*. (2017) indicated that the virulence genes (aerolysin, elastase, lipase) increased the pathogenicity of the bacterium *Aeromonas hydrophila* which is the causative agent of haemorrhagic septicaemia. Rezaie *et al*. (2017) recorded the trematode *Centrocestus formosanus* in the gills of fish referred to the veterinary hospital of Shahid Chamran University of Ahvaz, Khuzestan. Asgharnia and Ghasemi (2018) recorded monogeneans on the gills of fish from farms in Gilan such as *Dactylogyrus anchoratus*, *D. extensus* and *D. vastator*, with frequency of infection in *D. extensus* at 50% for example. Daghigh Roohi *et al*. (2019) genetically characterised 5,603 monogeneans found on 112 fish, the parasites being *Dactylogyrus achmerowi*, *D. anchoratus*, *D. extensus*, *D. minutus*, *D. vastator* and *Gyrodactylus sprostonae.* Daghigh Roohi *et al*. (2019) used morphometric and molecular nethods to identify *Gyrodactylus sprostonae* in Gilan fish farms. Mazandarani *et al*. (2019) studied the pathogenicity to carp fingerlings of the bacterium *Yersinia ruckeri*, which causes enteric redmouth disease. They found an $LC_{50}$ after 7 days until 21 days after challenge of $2.8 \times 10^8$ cells/fish, with damage to gills, kidneys and liver. Taheri Mirghaed *et al*. (2019) isolated the helminths *Anisakis simplex*, *Asymphyllodora tinca*, *Bothriocephalus acheilognathi* and *Caryophyllaeus fimbriceps* from the abdominal cavity of fish from the southeastern Caspian Sea, with 69.44% of fish infected with at least one kind of parasite. Taheri Mirghaed *et al*. (2019) carried out molecular and pathological studies on koi herpes virus on fish farms in Khuzestan, this disease being considered as one of the factors contributing to summer mortality syndrome in carp.

Ahmadivand *et al*. (2020) detailed cyprinid herpes virus 3 transmission in farmed carp, probably from imported ornamental koi. Akbari *et al*. (2020) showed that *Dactylogyrus* spp. through increasing DNA damage, increased levels of malondialdehyde and carbonylation proteins signifcantly and caused oxidative stress in infected gill tissue. Moumeni *et al*. (2020) recorded the zoonotics *Anisakis simplex* and *Anisakis* spp. from this fish in Iran. Rahmati-Holasoo *et al*. (2020) identified cyprinid herpesvirus 1 (CyHV-1), the causative agent of carp pox characterised by epidermal papillomas in common carp and other cyprinoids, in Iranian koi, the first record in the Middle East. Razi Jalali *et al*. (2020) used genomic DNA to detect

*Dactylogyrus* from fish on farms and local markets of Ahvaz, southwest Iran. *Dactylogyrus extensus* was isolated from common carp and phylogenetic analysis showed that they were clustered with some Iranian (Gilan), Chinese and Czech isolates. Importing fingerlings from Gilan Province could lead to introducing monogenean infections to native cyprinid fish. Asgharnia and Ghasemi (2021) examined external parasites on carp from fish farms in Gilan, reporting Protozoa (*Ichthyophthirius multifiliis* and *Trichodina* sp.) and Monogenea (*Dactylogyrus extensus*). Ehsanfar *et al*. (2021) recorded the prevalence and intensity of parasites from warmwater fish ponds at Dasht-e-Naz Agriculture Company in Mazandaran. Carp parasites were *Ichthyophthirius multifilis* and *Trichodina* sp. (Protozoa), *Dactylogyrus anchoratus*, *D. extensus*, *D. lamellatus* and *Gyrodactylus* sp. (Monogenea), *Bothriocephalus gowkongensis* (Cestoda) and *Lernaea* sp. (copepodid stage) (Crustacea). Ghasemi *et al*. (2021) reviewed prevention and control strategies and laboratory procedures for diagnosis of such viral diseases as spring viremia of carp, carp pox, koi sleepy disease (carp oedema virus) and koi herpes virus.

The Caspian seal, *Pusa caspica*, is a significant predator on this species (Krylov, 1984). Khaleghizadeh and Sehhatisabet (2006) noted that great grebes (*Podiceps cristatus*), great and pygmy cormorants (*Phalacrocorax carbo* and *Ph*. (= *Microcarbo*) *pygmaeus*) ate carp in Gilan and goosander (*Mergus merganser*) ate carp in Mazandaran. Carp were 97% of the diet of great cormorants in Gilan but 20% in Mazandaran where mullets formed 80%. Sooty gulls, little, common, Caspian, gull-billed and whiskered terns (*Larus hemprichii*, *Sterna albifrons*, *S. hirundo*, *S. caspia*, *S. nilotica* and *Chlidonias hybrida*) all ate carp in various parts of northern Iran. Barati *et al*. (2008) found pygmy cormorant chicks (*Phalacrocorax* (= *Microcarbo*) *pygmaeus*) and Ashoori *et al*. (2012) found that grey herons (*Ardea cinerea*) in the Siahkeshim Protected Area of the Anzali Wetland ate this species. Behrouzirad *et al*. (2013) found great cormorants at culture ponds in Shushtar, Khuzestan ate this fish at 70.78% compared to 9.8% for silver carp, 8.91% for grass carp, 5.85% for bighead carp and 4.41% for *Liza subviridis* (= *Planiliza subviridis*, greenback mullet). Ashoori *et al*. (2017a) recorded this species as an occasional item in the diet of young black-crowned night herons (*Nycticorax nycticorax*) in the Anzali Wetland. A wide variety of fishes and birds eat smaller carp as do predatory aquatic insects, frogs and toads. Many fishes eat carp eggs. The main predator of this species in the north Caspian Sea is *Sander lucioperca* (pike-perch), accounting for 65% of its food. *Silurus glanis* (European catfish) and *Esox lucius* (northern pike) and various birds such as the pelican are also important predators (Kushnarenko, 1978). On the spawning grounds, this fish could be picked up by hand and fell easy prey to birds and other predators.

Adult carp, however, are too large for most predators to take. A notable exception would be the mugger crocodile (*Crocodylus palustris*) in southeastern Iran that takes introduced carp (Mobaraki, 2015).

**Economic importance.** Balon (1974, 2006) detailed domestication of the carp, which has been a cultivated fish for over 2,000 years. The carp is an important table fish in neighbouring Iraq where details of farming techniques were given by Ahmed and Taher (1988) and by Mangalo and Akbar (1988a, 1988b). Kuliyev and Agayarova (1984) described catches in former Soviet waters of the Caspian Sea. In the southwestern part, size range was 21-64 cm in 1960-1961 (92% of fish were 29-41 cm) but in 1972 95% of fish were 31-55 cm. The smallest carp were caught in the southeastern Caspian where maximum weight was 3.97 kg as opposed to 10.0 kg in the central Caspian. Spawning fish in the southeastern Caspian were only 0.58-1.0 kg while in the southwestern Caspian carp were 0.25-5.75 kg. About 17-30% of

commercial catches in the Volga region were estimated to be comprised of hatchery production (Petr, 1987).

Curzon (1892) cited a catch of 300,000 carp in the Anzali Talab in a single day but this may have included several cyprinoid species. Nevraev (1929) gave catches for various fishing regions in Iran in the early twentieth century. For the Sefid River region from 1899-1900 to 1917-1918 the catch was 30 to 30,500 individuals with no fish reported in some years, and in Astrabad (= Gorgan) region from 1900-1901 to 1912-1913 the catch was 14,200 to 851,800 individuals. The commercial catch in Iran from 1956/1957 to 1961/1962 varied from 3,443 kg to 175,295 kg (Vladykov, 1964), from 1965/66 to 1968/69 varied from 184 to 333 tonnes (Andersskog, 1970) and from 1963 to 1967 from 7.0 to 108.8 t (on a yearly basis 41.1, 9.8, 7.0, 108.8, and 48.1 t respectively) (RaLonde and Walczak, 1970b). Catches from 1933/34 to 1961/62 varied from 34 kg to 1,113 t in the Bandar-e Anzali region and the total catch of the Northern Shilat (Fisheries Company) varied from 9.8 t to 333 t from 1963/64 to 1968/69 (RaLonde and Walczak, 1972). The Food and Agriculture Organization, Rome gave the catches from Iran for the six years 1980 to 1985 as 1,032, 2,000, 1,000, 52, 83, and 100 t respectively. The catch in the Anzali Talab in 1990 was 6,855 kg and from 1932 to 1964, the annual catch varied from 1.2-638.6 t (Holčík and Oláh, 1992). These wide fluctuations in reporting and in earlier nominal catches are indicative of the poor fisheries statistics as well as the inter-year variability of catches in Iran.

Vazirzadeh and Yelghi (2015) cited an annual wild common carp catch in the southeast Iranian Caspian Sea near 4-5,000 tonnes. Kalantarian *et al*. (2017) found that the beach seine fishery at Salmanshahr, Mazandaran caught 0.21 kg per seine haul (compared to 58.17 kg for *Rutilus kutum* and 53.47 kg for *Liza* (= *Chelon*) spp.) and this was the least abundant species caught at 0.18%. However, carp was the first species in fishermen’s income in Golestan Province (third in Gilan and Mazandaran) (Afraei Bandpei *et al*., 2017). March and April are the main fishing months in Iran (Farid-Pak, No date).

This species was the main fish in Iranian carp farms, when raised in polyculture with Chinese carps (Jalali and Molnár, 1990b). Farmed carp are preferred over wild-caught fish because of “little smell” (Japan International Cooperation Agency and CTI Engineering Co. Ltd., 2010). Salehi (2004b) gave a figure of 25% as the share of common carp in Iranian polyculture (63% being silver carp, replacing common carp from earlier reports) and gave a review of the economics of carp polyculture. Jaferian *et al*. (2019) carried out a feasibility study for polyculture with Chinese carps using water from the sugar cane fields of Khuzestan. The fish did not pose any risk for human consumption.

There were about 4,000 ha of carp fish ponds (which presumably included Chinese carps such as *Hypophthalmichthys* spp.) with an annual production of 2-3 tonnes/ha (White, 1988). Plans were made in the 1980s to increase total pond area (including trout which was at 60 ha and produced 1,000 t/year) to 35,000 ha over 10 years to yield an annual harvest of 100,000 t/year. However, Bartley and Rana (1998b) reported an aquaculture production of 6,561 tonnes in 1995 and Salehi (2004b) gave 28,060 t from warmwater fish farming, mostly Chinese carps. More than 700,000 carp fingerlings were released in the small and remote province of Chahar Mahall and Bakhtiari alone and 20 million carp, silver carp and grass carp fingerlings were produced in the Shahid Rajaei Hatchery in Sari for release across Iran in reservoirs and dams (*Abzeeyan*, Tehran, 4(7):VII, 1993). Salehi (1999) stated that the marketable size of cultured carp was 1 kg with most harvested once annually and almost 90% supplied to market in October-March with a peak in March (the Iranian New Year when fish is

a traditional food).

Kohnehchahry and Heydarpur (1973) outlined methods of raising carp using submerged cages which they believed would be suitable for Iranian waters and Raoufi *et al*. (2018) referred to cage culture in the Golestan Reservoir. Farabi (2017) and Vahid Farabi *et al*. (2017) also suggested that cage culture in the southern part of Caspian Sea was feasible and Aghili and Aghaei Moghaddam (2018) referred to pen culture in the Khozeini Canal, Gorgan Bay. Hosseinjani *et al*. (2020) reviewed the status of cage aquaculture in Iran and the world, noting Iranian production was 10,162 t, equal to about 2.2% of the total aquaculture production in Iran.


Lorestan, Khorramabad, carp farming billboard, 2000, Brian W. Coad.

Marjan Iran Company was selling 1,500-1,800 g fish for U.S. $1.90/kg in August 2003 compared to $2.10 for *Ctenopharyngodon idella* (source was http://groups.yahoo.com/groups/hilsa/message/25 but now inactive). In Golestan Province, carp cost 1,500-1,700 tomans/kg in the early 2000s (1 toman = 10 rials; exchange rates with U.S. dollars have fluctuated widely). Aghili *et al*. (2017) evaluated carp production in Golestan and found that with an average stocking density of larvae at 1,955/ha, harvested carp were at 2,533 kg/ha. The average profit, benefit-cost and rate of return of investment were 29,000 rials/kg, 6.2 and 50% respectively. Salehi (2006) analysed the consumer market for carp and its products in Iran. Shabanpour *et al*. (2007) investigated preparation of surimi from this species.

Moradinasab *et al*. (2015) noted the presence of carp in the kilka by-catch (*Clupeonella* spp., Clupeidae) on the Bandar-e Anzali fishing grounds although it, along with five other species, only comprised 0.2% of the kilka catch.

An exotic species in some parts of the world, common carp are a nuisance because they uproot vegetation used by native species for cover, food and spawning. This activity also increases water turbidity to levels that many native fish species cannot tolerate. Stirred up silt may smother eggs of native species. Carp also compete with other species for food and eat the eggs of other fish species. They also affect populations of invertebrates, amphibians and waterfowl and compromise sport fishing and the tourism industry. Vilizzi *et al*. (2015) examined 129 laboratory and field experiments in 19 countries world-wide and only the populations in one country could be considered as “no risk”.

This species is actively angled for along the Caspian shore of Iran and in its rivers (e.g., see Noorbakhsh (1993a)), appears regularly in fish markets of Ahvaz, Khuzestan and is caught by anglers there using bread or potato as bait. Adeli (2014b) listed rivers and reservoirs across Iran where this species was fished for by anglers.

The roe or eggs of this species have been implicated in poisoning (Halstead, 1967-1970; Coad, 1979) and should be avoided (see under the genus *Schizothorax* for more information on egg poisoning). Fish should be carefully cleaned in the spawning season to remove the eggs and ensure against contamination of flesh. Severe cases of egg poisoning in other species have resulted in death. However, Nina G. Bogutskaya (pers. comm., May 2011) noted that carp roe is eaten at Astrakhan on the lower Volga River and Adeli and Namdar (2015) mentioned the eggs of this species as a caviar substitute. This species is also converted into fish burgers and fingers, cake, mince, sausages and surimi in Iran (see below).

Robins *et al*. (1991) listed this species as important to North Americans. Importance was based on its use in aquaria and aquaculture, as food, in textbooks, for sport, as an experimental species and because it has been introduced outside its natural range. Brightly coloured varieties of carp are known as koi and are kept as ornamental fish. Colours include red, orange, white, black, blue and yellow in various combinations and patterns.

**Experimental studies.** The common carp is the most extensively investigated species in Iran for experimental studies, a reflection of its fishery for food, aquaculture importance and ready availability from fish farms for studies in the laboratory. The last two decades have shown a large number of works on this species. These are grouped below by subject matter and by five-year groups, the latter showing the progressive expansion of studies in, for example, pollution from heavy metals, herbicides and pesticides. Where an author(s) studied a particular topic, these may be grouped together irrespective of year. Certain topics may appear in different sections as they are studied in combination, e.g., stress may be a study on its own or may be combined with a study on feeding, growth, survival, etc. These studies are not replicated in each section and readers should search other sections for this additional information.

*Pollution:*-

Khazraiinia *et al*. (2001) studied the effects of experimental acute ammonia toxicity on serum enzymes, urea and cholesterol. Rostami Bashman *et al*. (2001) found histopathological lesions after exposure to cadmium, copper, mercury and zinc compounds. Arabi and Heydarnejad (2002) demonstrated the deleterious effects of copper and mercury, used in combating algal blooms and weeds, on the gills of carp. The immune response of carp following exposure to the insecticide malathion was studied by Soltani *et al*. (2003). Ebrahimi (2004) described the deleterious effects of copper, a pollutant, on sperm anatomy.

Arabi (2005) described cell membrane and DNA damage to gills from metal ion-mediated oxidative stress. Karami *et al*. (2005) found river fish had greater exposure to organophosphorus compounds than Caspian Sea and well-fed fish. Oryan *et al*. (2005) described the effects of baclofen (a central nervous system depressant and skeletal muscle relaxant) on the pituitary system. Sharifpour *et al*. (2005) showed the highly toxic effects of the pesticide endosulfan (with an $LC_{50}$ of less than 0.1 mg/l). Ghiasi and Mirzagar (2006) studied the lysozyme content in sublethal concentrations of cadmium. Naji *et al*. (2007) found a toxic effect of zinc sulphate on gill tissues, which suffered hypertrophy and hyperplasia and Naji *et al*. (2007) found the $LC_{50}$ 96 h value of cobalt chloride was 327-328 mg/l. Darafsh *et al*. (2008) used scales as an indicator of heavy metal pollution. Golchinrad *et al*. (2008) listed the effects

of detergent on liver glycogen (decreased) and glucose (increased). Shamloufar and Haji Moradlou (2008) determined the $LC_{50}$ 96 h of the insecticide sevin was 14.187 mg/l for juveniles and therefore toxic, symptoms including lordosis, loss of balance, swimming in half circles, pigmentation changes and blocking of respiration, as well as various histopathological changes. Vaezzadeh *et al*. (2008) showed that the levels of the pesticide heptachlor in fish from Anzali and Ramsar could have a health risk to consumers. Banaei *et al*. (2009) found sublethal effects of the agricultural pesticide diazinon on ovaries and testes, which showed degenerative changes, Banee *et al*. (2011) described haematological and histopathological changes while Banaee *et al*. (2012) studied the effects on biochemical blood parameters and liver histopathology. Davodi *et al*. (2009) investigated organochlorine pesticides in fish from the Shadegan Wetland but the mean levels were not harmful for human consumption. Mohammadnezhad Shamoushaki *et al*. (2009) determined the $LC_{50}$ 96 h for the insecticide endosulfan was 0.0046 mg/l, above the maximum allowable concentration at 0.00046 mg/l. Rostami and Soltani (2009) examined the histopathological effects of the aquaculture pollutant copper sulphate. Safaeian *et al*. (2009) found the gut bacteria of Anzali Lagoon fish had a high resistance to three antibiotics (ampicillin, streptomycin and tetracycline) with evident human health implications, and the resistance of the bacteria to such heavy metals as cadmium, copper and mercury increased the number of bacteria resistant to antibiotics. Shapouri *et al*. (2009) showed that fish exposed to copper at 2-6 mg/l suffered liver and gonad damage but none to muscle tissues, and most accumulation was in the liver.

Elsagh (2010) determined levels of the heavy metals cadmium (1.353), copper (9.144), iron (85.887) and zinc (mean 30.204 mg/g) in fish from the Caspian Sea. Ghiasi *et al*. (2010, 2010) examined the effects of low concentrations of cadmium on the immune response in winter and on haematology and serum biochemistry, for example decreasing white blood cell counts and increasing lactate dehydrogenase. Mohammad Nejad Shamoushaki *et al*. (2010) found the lethal concentration ($LC_{50}$ 96 h) of the herbicide roundup (glyphosate) used in agriculture was 7.716 mg/l. Ansari and Raissy (2011) found fish from the Beheshtabad River had mean concentrations of 125.5, 189.4 and 75.2 μg/kg for copper, iron and zinc, attributable to fertilisers from agriculture, but levels were safe for human consumption. Bandani *et al*. (2011) showed how concentration of the heavy metals cadmium, chromium, lead and zinc in muscle and liver of fish from Gomishan Marsh and Gorgan Bay, were lower than allowable concentrations according to international standards. Elsagh (2011) found Iranian fish fillets with cadmium and lead levels above accepted limits for human consumption. Ghiasi *et al*. (2011) used naturally occurring Iranian zeolite, an ion-exchanging agent, in water contaminated with cadmium to reduce levels of this heavy metal in fish tissues. Ghovati *et al*. (2011) monitored changes in hardness and alkalinity on the toxicity of zinc. Malekpouri *et al*. (2011) showed short-term disturbances of serum parameters related to bone metabolism by waterborne cadmium. Pazooki *et al*. (2011) worked on heavy metal (lead, copper, zinc) levels in cultured carp and found they were not a health problem. Peyghan *et al*. (2011) detected the illegal antibiotic furazolidone in cultured carp in Khuzestan. Tabatabaie *et al*. (2011) found higher mercury concentrations in carp, an omnivorous benthic/pelagic species (Anzali Wetland: 0.2 μg/g wet weight; Gomishan Wetland: 0.2 μg/g), than in *Sander lucioperca* (pike-perch), a carnivorous pelagic species (Anzali: 0.06 μg/g; Gomishan: 0.15 μg/g). Teimouri *et al*. (2011, 2011) examined levels of polychlorinated biphenyls in fish from Abkenar in the Anzali Wetland, where strong correlations were found between fish tissue and filtered suspended particles and levels were less than some acceptable standards and more than another standard.

Zakipour Ziadloo *et al*. (2011) found that allicin, a garlic component, alleviates tissue injury following lead poisoning. Zare-maivan *et al*. (2011) examined Arvand River fish for pollutant residues and found polychlorinated biphenyls and organochlorines but no organophosphates, and levels were within acceptable limits. Abedi *et al*. (2012, 2013) found carp were more tolerant to heavy metal (cadmium, chromium, lead) exposure than an exotic catfish (*Pangasius hypophthalmus*), perhaps because of the scaly body compared to the scaleless catfish, with scales absorbing some of the heavy metals leading to less in edible tissues. Abedi *et al*. (2012) showed that chromium absorption was 3.65 times greater in unscaled catfish (*Pangasius hypophthalmus*) than in scaled carp and absorption was in the sequence of gills>liver>skin>scales>muscles. The scales in carp absorbed a metal toxicant and rendered muscle tissue safer for consumption. Dehghani *et al*. (2012) described the copper bioaccumulation patterns of common and mirror carp. Elsagh (2012) found levels of cobalt, copper and zinc were higher than acceptable limits for Caspian Sea fish. Hatami and Sieyahchehreh (2012) studied the effect of ethidium bromide, used in medical and biological laboratories and flushed to the environment, finding it to be a chemical stressor to carp by altering the number of blood cells and affecting the homeostasis of the circulatory system. Javadanekherd *et al*. (2012) measured the amount of organic chlorine pesticides and polychlorinated biphenyls in carp, *Carassius auratus* and *Esox lucius* (northern pike) in the Anzali Wetland, finding carp had the highest levels of contaminants but levels were within global standards. Khoshnamvand and Kaboodvandpour (2012) reported on total mercury in white and red muscle tissues in fish in the Sanandaj Gheshlagh (= Qeshlaq) Dam, Kordestan, the level being higher than established limits for human consumption in fish weighing over 500 g. Mashinchian Moradi *et al*. (2012) used single cell gel electrophoresis to evaluate DNA damage in fish exposed to the insecticide malathion, finding higher damage in blood cells with higher doses and showing DNA strand breakage could be used in ecotoxicological studies. Moradi *et al*. (2012) found significant DNA damage by the herbicide butachlor used extensively in northern Iran. Saeedi Saravi *et al*. (2012) found carp in the Gomishan Wetland had the highest heavy metal pollution, higher than in *Rutilus kutum* and other species, below allowable limits but a cause for concern as levels in water were increasing. Shahsavani *et al*. (2012) determined the efficacy of allicin (an organosulphur compound from garlic) in preventing lead-induced oxidative damage to various body organs. Shayegi *et al*. (2012) found fish from the Gorgan and Qarasu (= Qareh Su) rivers had higher than permitted levels of the insecticides azinphos methyl and diazinon, reflecting the levels in the water. Abedi *et al*. (2013a, 2013b) showed sublethal concentrations of cadmium, chromium and lead were differentially toxic to this species, affecting enzyme activities, which could be used in biomonitoring. Abedi *et al*. (2013) described the haematology and biochemistry of exposure to chromium, various parameters being affected reflecting a stress reaction. Alian *et al*. (2013) investigated alterations in tissue enzymes reflecting metabolic disturbances due to chronic cyanide intoxication. Askary Sary and Velayatzadeh (2013) found fish from Sarcheshmeh Market, Tehran had levels of lead and zinc in liver and muscle above acceptable limits. Baghshani and Shahsavani (2013) found evidence that exposure to lead acetate affected enzyme activity in various organs. Banaee *et al*. (2013) determined a level of the agricultural insecticide chlorpyrifos as low as 40 μg/l could cause biochemical and behavioural changes in this species. Gholami SeyedKolaie *et al*. (2013) examined the effects of the pesticides carbaryle, glyphosate and malathion on fingerlings finding the $LC_{50}$ 96 h levels were 12.67, 6.75 and 1.3 mg/l respectively. Jalali Mottahari *et al*. (2013) showed how fish were impacted

by a change in pH and by the heavy metal copper in alkaline water, affecting haematological and biochemical parameters. Javahery Baboli *et al*. (2013) analysed lead concentrations in tissues of fish, sediments and water from farms in Khuzestan, finding no differences between the farms, tissue concentrations were in the order muscle>liver>gill with muscle levels higher than acceptable limits, and no significant differences between farms for sediments and water levels. Khoshnamvand *et al*. (2013) studied fish in the Sanandaj Gheshlagh (= Qeshlaq) Dam, Kordestan, a mercury polluted lake, where mercury levels in fish over 850 g were greater than allowable limits. Majnoni *et al*. (2013) recorded metal concentrations in fish from Zaribar Wetland where these decreased in the sequence copper>lead>mercury>nickel>cadmium and the fish posed no health risk for human consumption. Mortazavi *et al*. (2013) found endocrine disruption chemicals (bisphenol A, 4-nonylphenol and octylphenol) in muscle and liver of fish from the Anzali Wetland. Naji *et al*. (2013) determined the $LC_{50}$ 96 h of ferrous iron in fry as 1.85 mg/l. Nasehi *et al*. (2013) found a positive correlation between the high levels of bioavailable heavy metals (cadmium, copper, iron, lead, mercury, nickel, zinc) in the Aras River and their concentration in the fish body. Panahandae *et al*. (2013) examined levels of cadmium, chromium and lead in fish from the Anzali Talab and found lead levels exceeded international standards. Saeedi Saravi and Shokrazadeh (2013) found the highest heavy metal content in this species compared to other species along the Gorgan coast. Askary Sary and Karimi Sari (2014b) measured iron levels in fish from the Azadegan Warmwater Fish Culture Centre in Khuzestan where there was no risk for human consumption. Farhangi *et al*. (2014) determined the $LC_{50}$ 96 h for zinc as 129.07 mg/l with maximum mortalities (>80%) occurring in the first 7 hours of exposure. Ghelichpour (2014) noted that copper caused a stress response and sodium loss. Mansouri *et al*. (2014) showed that muscle concentrations of cadmium, copper, lead and zinc in fish from Qeshlaq Dam were lower than Food and Agriculture Organization standards. Mohiseni *et al*. (2014) showed that adding rose mallow extract (*Althaea officinalis*) to the diet of juveniles improved physiological tolerance to heavy metals. Nasrollahzadeh Saravi *et al*. (2014) observed various polycyclic aromatic hydrocarbons in muscle tissue of Caspian Sea fish, and these could endanger human health. Nesar Hosseini and Askary Sary (2014) determined the zinc hazard quotient in cultured fish from Khuzestan Province and found no risk to humans. Olyaei Seyedeh *et al*. (2014) studied pyrene oil effects and found the histopathology showed negative effects on homeostasis, fish health and vital organs. Rezaei *et al*. (2014) found iron oxide nanoparticles in low doses increased red blood cell counts while a higher dose reduced counts. Rostami and Askary Sary (2014) determined the copper hazard quotient in cultured fish from Khuzestan Province and found no risk to humans. Shiry *et al*. (2014) showed how the insecticide malathion was moderately toxic to this fish affecting blood indices, with a median lethal concentration of 1.3 mg/l, a lowest effective concentration of 0.646 mg/l, and a maximum allowable concentration of 0.13 mg/l. Sobhan Ardakani and Jafari Seyed (2014) found that the levels of copper, lead and zinc in edible parts of fish from the Shirinsu Wetland of western Iran did not pose a health concern for consumers. Sobhanardakani and Jafari (2014b) showed concentrations of arsenic, cadmium, copper, lead, mercury and zinc in Taham Dam fish were significantly lower than permissible levels. Younesipour *et al*. (2014) found southern Caspian Sea fish had metal concentrations in edible tissue in the order iron>copper>manganese>cobalt>nickel but these were not ecotoxicological threats.

Abdollahpour *et al*. (2015) showed that fish exposed to the organic phosphorus insecticide diazinon in the presence of *Azolla* (duckweed) were less stressed as duckweed

removed phosphorus from the water. Ariyaee *et al*. (2015) found heavy metal concentrations in fish from the Chahnimeh Reservoirs in Sistan were below the levels of concern for human health. Banaee *et al*. (2015) showed that immature carp exposed to municipal wastewater at Behbehan suffered from endocrine disruptors, which may cause dysfunctional reproduction. Bita *et al*. (2015, 2016) synthesized silver nanoparticles using seaweed (*Sargassum angustifolium*) and studied their toxicity, finding an $LC_{50}$ 96 h of 11.34 mg/l. Darabitabar (2015) found a $LC_{50}$ 96 h for juveniles of 697.18 p.p.m. for commercial diesel. Esfandiar *et al*. (2015a) determined the insecticide chlorpyrifos, where the maximum allowable amount in nature was 0.051 mg/l, had an $LC_{50}$ 96 h of 0.516 mg/l. Esfandiar *et al*. (2015b) found sublethal concentrations of chlorpyrifos caused variations in serum biochemical parameters. Ghiasi and Mirzagar (2015) demonstrated the ion-exchanging agent zeolite significantly reduced exposure to sub-lethal concentrations of cadmium. Hedayati and Jebaleh (2015) determined the $LC_{50}$ 96 h for cadmium chloride was 9.77 mg/l, considered rarely toxic. Hedayati *et al*. (2015) found that zinc oxide nanoparticles were lethal ($LC_{50}$) to carp at 3.12 p.p.m. exposed over seven days and there were various negative impacts on haematological indices. Zinc is an essential element in organisms, cannot be stored in the body, and must be provided through food. Kafilzadeh (2015) found of the organochlorine pesticide residues (chlordane, DDT, DDE, endosulfan, heptachlor and lindane) analyzed in four sites at four seasons from the Lake Tashk area, DDE was higher in “carp” than in water and lower in “carp” than in sediment. Khandan Barani and Dahmardeh (2015) and Khandan Barani *et al*. (2016) studied the recovery of gills and liver after exposure to sublethal concentrations of ammonia, gill filaments requiring less time to recover than liver tissue. The activity of various metabolic enzymes in the liver were affected, tissue damage to gills occurred and biochemical serum parameters changed. Khanipour *et al*. (2015) found no significant differences in cobalt and nickel levels in carp edible tissues from different stations in the Anzali Wetland and the fish were suitable for human consumption. Maktabi *et al*. (2015) recorded mercury concentrations in 45 fish farms along the Karun River, Khuzestan in muscle, liver and gill tissues, and in water and sediments, finding levels in muscle from central and southern sites were above the maximum tolerable limits. Maleki *et al*. (2015) found heavy metals in fish from Sanandaj Gheshlagh (= Qeshlaq) Dam, Kordestan but edible muscle levels were not of concern for human consumption. Mansouri *et al*. (2015) showed levels of the heavy metals cadmium, chromium, copper, lead and zinc in edible parts of fish from the Sirvan River were below the level of concern for human consumption. Masoumi *et al*. (2015) found the severity of toxic effects of nanosilver on fish red blood cells and liver tissue was directly related to concentration and duration of exposure. Nejatkhah Manavi and Kiadehy (2015) examined levels of the pesticide lindane in muscles of fish from Astara, Bandar Anzali, Bandar-e Torkeman, Chalus, Fereydun Kenar, Hashtpar, Khazarabad Sari and Kiashahr, finding Chalus to be the most polluted and a declining trend in pesticide amount in recent years. Radkhah *et al*. (2015a) indicated the various haematological parameters strongly influenced by lead exposure such as elevation in red blood cells, glucose and total cholesterol, and decrease in vitamin C activity, phagocyte activity, and others. Abedi *et al*. (2016) examined the histopathological changes to gill tissues in fish exposed to the heavy metal chromium, which could be used to assess environmental contamination. Ahmadi *et al*. (2016) found that copper oxide nanoparticles at 50-200 mg/l sublethal concentrations had negative effects on juveniles in terms of haematological indices and damage to gill tissues. Askari Hesni (2016) showed that changes in thyroid hormones in carp exposed to sublethal concentrations of cadmium could be used as a biological indicator in

determining the health of the aquatic environment. Bashirzade Hengami and Oujifard (2016) investigated the accumulation of cadmium, copper, iron, lead, nickel and zinc in fish from the Anzali Wetland and found fish were suitable for human consumption. Bita *et al*. (2016) synthesized silver nanoparticles using seaweed (*Sargassum angustifolium*) and found increasing concentrations significantly reduced bacterial flora on the skin. Deldar *et al*. (2016) found that copper nanoparticles, and use of alfalfa as a protective, showed gill vacuolation, curving and hyperplasia in gill filaments, hyperplasia in skin and increase in skin mucus cells. Esfandyar *et al*. (2016) found long-term exposure to the agricultural pesticide chlorpyrifos at 0.05 and 0.1 mg/l caused changes in liver and oxidative enzymes. Forouhar Vajargah *et al*. (2016) found the pesticides abamectin and pretilachlor were moderately toxic to carp. Ghomi (2016) determined arsenic, cadmium, lead and mercury levels in the muscle of fish from the Gomishan and Anzali wetlands and the southern Caspian Sea, finding them to be acceptable with least pollution in the middle sample from the southern Caspian, which had deeper water and more water circulation, and the highest pollution in the western site. Ghorbanzadeh Zafarani *et al*. (2016) found no interaction between sub-lethal levels of lead on blood iron in pond-cultured fish from Babol. Golshani (2016) found that toxin accumulation in fish from five estuaries on the Caspian Sea of Iran was strongly controlled by habitat and feeding habits. The herbivorous carp had the middle-level toxin concentration, less than the detritivore *Liza aurata* (= *Chelon auratus*, golden mullet) and more than the carnivore *Rutilus kutum*. The acetylcholinesterase enzyme activity was gradually inhibited with increase in organophosphorus pesticide concentration. Khanipour *et al*. (2016a) measured the accumulation of cadmium and lead in edible tissues of carp from the Anzali Wetland and found the fish to be suitable for human consumption. Khanipour *et al*. (2016b) examined chromium, copper and zinc from the same locality and found the fish to be suitable for human consumption. Khoshnamvand *et al*. (2016) compared the concentration of accumulated mercury in muscle tissue of different sizes of carp from the Shadegan Wetland, and those weighing more than 500 g were higher than the limit allowed by international standards. Maktabi and Romiani (2016) compared iron concentrations in muscle, liver and gill tissues of farmed fish in Khuzestan, the order being gill>liver>muscle with the latter at 0.5 p.p.m. and higher than an acceptable standard. Malekpouri *et al*. (2016) determined that hypoxia could act as a limiting stressor while cadmium was a loading stressor. Malekpouri and Mahboobi Soofiani (2016) found that sublethal doses of water-borne aluminium produced hypothyroidism. Mansouri *et al*. (2016) co-exposed carp to nanoparticles of titanium dioxide and copper oxide and found severity and incidence of injuries to gills, intestine, liver and kidney, as well as hyperactivity, loss of balance and convulsions, were higher than either nanoparticle alone (nanoparticles are photocatalysts used to eliminate organic pollutants). Namroodi *et al*. (2016) showed that sublethal concentrations of cadmium caused increasing inflammation to gills while the liver was able to control some inflammation over time. Niki *et al*. (2016) found no significant effect on gut bacteria of silver nanoparticles, which had an $LC_{50}$ 96 h of 0.23 p.p.m. Ojifard *et al*. (2016) examined the effects on juveniles of exposure to the biopesticide neem azal (Indian lilac, *Azadirachta indica*) and found reduced growth but no effect on survival, abnormal behaviours, and damage to gill tissues. Poshtpanah *et al*. (2016) found the acute toxicity of the herbicide glyphosate in fry was 68.83 p.p.m., regarded as low toxicity. Sharifinasab *et al*. (2016, 2016) showed that combined diet supplementation with vitamin C and chitosan may improve the detoxification system in muscles, prevent oxidative stress and inhibit changes in blood biochemical parameters, and thus protect carp from toxicity

of the herbicide paraquat. Shokrzadeh *et al*. (2016) found diazinon levels in fish from the central coast of the Caspian Sea were acceptable for human consumption. Askari Hesni and Naqshbandi (2017) studied the effects of glyphosate on gill structure, finding hyperplasia and hypertrophy of gill cells, vacuolation, epithelium cells lifting in secondary lamella, club-shaped lamellae, aneurism, oedema, adhesion of secondary filaments, and degenerative and necrotic changes of gill filaments and secondary lamellae, increasing with dosage, and of potential use as a biomarker. Askary Sary and Karimi Sary (2017) found fish from the Azadegan Warmwater Fish Culture Centre in Khuzestan had iron levels with a hazard quotient of 0.63 and, at less than 1.0, there was no risk to human health. Fazilat *et al*. (2017) compared the singular and combined effects of dimethoate pesticide and bacilar bio-fertiliser on blood parameters and found the latter effects were significantly different. Hedayati *et al*. (2017) indicated that a 50% lethal concentration of nanoparticles of copper, titanium and zinc caused tissue damage and destruction and also sub-lethal toxicity of nano-zinc oxide was higher than nano-copper oxide and nano-titanium dioxide and caused much wider effects on gill tissue. Hedayati and Darabitabar (2017) calculated the $LC_{50}$ 96 h of vertimec insecticide as 1.243 mg/l and, when the prebiotic isomaltooligosaccharide was added to the diet at 1 mg/kg, no positive effect on intestinal tissue was found. Heshmati *et al*. (2017) compared wild and farmed fish for toxic and trace elements (arsenic, cadmium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium and zinc) in muscle tissue of fish from the southwest Caspian Sea, finding arsenic to be below the detection limit, iron was the highest concentration in both wild and farmed fish, cadmium, lead, mercury and manganese were higher in wild fish, others showed no difference between wild and farmed fish, and the estimated daily intake for humans was acceptable and hazard quotient values showed no health risk to consumers. Hoseini (2017) found that the insecticide danitol was very toxic and caused oxidative stress in carp and the stress could be monitored by measuring the activity of erythrocyte antioxidant enzymes. Hoseyni *et al*. (2017) studied the effect of photocatalytic titanium dioxide nanoparticles (used to reduce the toxicity of crude oil) on carp exposed to the water-soluble phase, finding a reduction in gill damage. Hosseinzadeh *et al*. (2017, 2018) assessed the harmful effects of 4-nonylphenol (prevalent in the environment, an endocrine disrupter and estrogen-like) on plasma vitellogenesis, steroid hormones, plasma IgM immunoglobulin and lysozyme activity, and hepatosomatic and gonadosomatic indicators in immature koi carp. Hosseinzadeh Sahafi *et al*. (2017) showed that the 4-nonylphenol could cause immunological disruption and increase susceptibility to disease in koi carp. Khanipour *et al*. (2017) found carp from the Anzali Wetland were unfit for human consumption because of the levels of the hydrocarbon benzo(a)pyrene, while *Carassius auratus* and *Rutilus kutum* were edible. Machanlu *et al*. (2017) found that nanoparticles of titanium dioxide under UV radiation removed toxic components of crude oil and increased growth indices in the fish. Mehrabian Fard *et al*. (2017) found that dietary supplementation with spirulina (the dried biomass of *Spirulina* (= *Arthrospira*) *platensis*, a blue-green alga) had an ameliorating effect on cyanide-induced oxidative damage in tissues, useful for fish inhabiting polluted environments. Mohammadi Otaghsra *et al*. (2017) found that as the amount of the pesticide diazinon fish were exposed to increased, white blood cell count decreased. Mojoudi *et al*. (2017) gave an $LC_{50}$ 96 h of 62.76 mg/l for lead nitrate ($Pb(NO_3)_2$). Namvazadeh *et al*. (2017) found fish from an aquaculture farm in Khuzestan had negligible levels of mercury since the fish were fed haelthy diets and not exposed to a natural food chain. Naqshbandi *et al*. (2017) showed that fish exposed to lead doses below the threshold had increased blood glucose, serum cholesterol and triglyceride

levels. Omidzahir *et al*. (2017) assessed the iron concentration in skin and muscle tissues after exposure to iron oxide nanoparticles, finding higher levels in skin. Pakzad *et al*. (2017) used carp from the Chagha Khur Wetland to study the physiochemical and morphological effects of cadmium accumulation and discussed methodologies to use. Sahraei *et al*. (2017) examined changes in muscle and liver enzymes of fish fed food with iron and zinc nanoparticles, finding iron ones caused more rapid deterioration in muscle than zinc ones and liver enzyme levels increased. Salemi and Hosseini Alhashemi (2017) examined bioaccumulation of cadmium, chromium, lead, nickel and zinc in carp muscle at Dezful, Khuzestan and found cadmium, lead and nickel were at levels higher than international standards and consumption was a serious threat for consumers. Sepidnameh *et al*. (2017) showed that incorporating Persian thyme (*Zataria multiflora*) in the juvenile diet decreased the harmful effects of cadmium better than vitamin E. Sinka Karimi *et al*. (2017) carried out a review and meta-analysis of lead concentrations in fish from the southeastern coast of the Caspian Sea and found a great difference between the various studies in terms of the reported effect factor. Current consumption led to no serious health risk and 0.28 kg/day for adults and 0.58 kg/day for children was without effect. Zangani *et al*. (2017) found that the herbicide oxadiazon was highly toxic to carp and caused significant changes in haematological and biochemical parameters and had mutagenic potential in erythrocytes. Aghili and Aghaei Moghaddam (2018) assessed heavy metals in water and sediment before and after rearing of carp in pen culture in the Khozeini Canal, Gorgan Bay, finding levels generally were less than global limits except for iron in sediment. Alishahi *et al*. (2018) found the $LC_{50}$ 96 h of silver nanoparticles L2000 was 0.099 mg/l and of Ls2000 was 0.094 mg/l. Amaninejad *et al*. (2018) tested immature koi carp from a Tehran hatchery for their reaction to the endocrine disrupting surfactant chemical 4-nonylphenol ethoxylate with 17-β-estradiol and found a disturbance to the balance of the immune system and ultimately death of the fish. Banaee *et al*. (2018) and Sharifinasab *et al*. (2018) administered the natural antioxidants vitamin C and chitosan to protect against changes in biochemical parameters of gill cells exposed to the herbicide paraquat but these had only minor effects and did not return the parameters to normal levels as toxicity of this herbicide is severe. Derakhshan *et al*. (2018) studied heavy metal levels in fish consumed in Shiraz. Mean concentrations of cadmium, copper, lead and zinc were 0.07, 0.59, 0.23 and 0.47 mg/kg dry muscle weight respectively, acceptable by permissible international standards. Forouhar Vajargah *et al*. (2018) found that sublethal concentrations of copper nanoparticles could lead to serious tissue lesions such as gill damage and concentrations above 30 ml/l could lead to such clinical signs as skin darkening and even death, the $LC_{50}$ 96 h of CuO nanoparticles being 124.9 mg/l. Ghelichpour and Taheri Mirghaed (2018) found the pesticide indoxacarb increased the expression of the Hsp70 gene in different organs, indicating osmotic and oxidative stress. Kashiri *et al*. (2018) examined the effects of the pesticide glyphosate and found chronic concentrations caused renal tubular necrosis, bleeding and urethral hypertension, and these could be used as a bio-indicator of glyphosate effects on carp. Khoshnamvand *et al*. (2018) traced the pathway of mercury from sediments to benthos to carp as a benthivorous fish in the Sanandaj Qeshlaq Dam, Kordestan. Transmission from sediment to benthos was not considerable but biomagnification occurred from benthos to fish so health considerations have to be taken into account for human consumption of fish from this dam. Khosravi Katuli *et al*. (2018) revealed the adverse effects of silver nanoparticles on various aspects of the health of juveniles, probably related to accumulation of silver followed by molecular and oxidative stress. Khosravi Katuli *et al*. (2018) also examined the effects of sub-

lethal concentrations of silver nanoparticles and silver nitrate and found a significant increase in the Hsp70 gene (heat shock protein upregulated by heavy metals) expression and the most tissue effects were in the liver. Majlesi *et al*. (2018) found that levels of cadmium and mercury in fish from the Khersan River (upper Karun River basin) were at levels safe for human consumption while lead levels exceeded global standards. Mazandarani and Darvishi (2018) found the maximum sub-lethal concentration of unionized ammonia for fingerlings was 0.12 mg/l. Mohammadi *et al*. (2018) and Mohammdi Movahed *et al*. (2019) found antioxidant enzymes and malondialdehyde levels could be used to monitor oxidative stress in juvenile carp exposed to iron oxide nanoparticles (widely used in nuclear magnetic resonance imaging and chemotherapy). Mohiseni *et al*. (2018) demonstrated that the feed additive pectin could potentially ameliorate the harmful effects of heavy metals such as cadmium. Mohseni *et al*. (2018) showed that fish exposed to the agricultural fertilisers dimethoate and/or bacilar bio-fertiliser had decreased innate immune responses. Nemrodi *et al*. (2018) showed that a sub-lethal concentration of cadmium increased cytochrome $P_{450}$ CYP1A gene expression, a gene sensitive to contamination. Omidzahir *et al*. (2019) demonstrated that the effect of iron oxide nano-particles on small intestinal tissue was dependent on dose and duration of exposure. Damage was done to intestinal epithelial cells, including enterocytes, villi and goblet cells. Iron accumulation in the small intestine eventually declined after day 21 days despite increasing the dosage. Seifzadeh *et al*. (2018) found bioaccumulation of the pesticides aldrin, diazinon and endrin in muscle tissues of fish from the Anzali Wetland was lower than international detection limits and so consumers were not at risk. Solgi *et al*. (2018) analysed cadmium, cobalt, copper, lead and manganese levels in muscle tissue of carp from Nowshahr on the Caspian Sea coast and found them to be within acceptable limits. Solgi *et al*. (2018) found lead and cadmium levels in fish from the Gomishan and Zarivar wetlands did not pose a health risk for human consumption. Takesh *et al*. (2018) found a mean lead concentration of 0.2 mg/l in carp from the Choghakhor (= Chagha Khur) Wetland, lower than the maximum acceptable level, but extensive agricultural activities on the wetland were likely to gradually increase the risk. Veisi *et al*. (2018) investigated haematological indices of fry exposed to iron nanoparticles and treated with the probiotic *Lactobacillus,* finding the detrimental effect of the iron was offset by the probiotic. Ziaeinejad *et al*. (2018) exposed carp to silver nanoparticles and found that the highest accumulation was in muscle tissue and the lowest was in gills, and survival at end of 60 days showed a slight decline with increasing concentrations of nanoparticles. Zolfaghari (2018) found lead and mercury concentrations in muscle tissue of fish from Sistan were lower than World Health Organization limits. Banaee *et al*. (2019) evaluated the use of zinc oxide nanoparticles in the diet and found supplements at 10 and 15 mg caused severe cytotoxic effects including blood biochemical parameters. The primary toxic mechanism was possibly an increase in cellular oxidative stress and disrupting biochemical function of cells. Banaee *et al*. (2019) examined blood biochemical changes in carp co-exposed to paraquat and titanium dioxide nanoparticles, the latter being a photocatalyst used to eliminate organic pollutants. Using 0.125 mg/l nanoparticles in order to remove 0.2 mg/l paraquat minimised the adverse effects of the latter and its metabolites on blood biochemical indices. Simakani *et al*. (2018) showed that exposure to the fungicide mancozeb used in agricultural fields of the Caspian region caused a stress response, health problems and tissue damage in fingerlings. Vazirzadeh and Fazilat (2018) examined the combined effects of dimethoate pesticide and bacilar bio-fertiliser used in agriculture and appearing in runoff, finding no remarkable differences with singular effects on blood biochemistry. Azari *et al*. (2019) showed that sub-lethal

concentrations of multi-walled carbon nanotubes had adverse effects on serum biochemical parameters. Forouhar Vajargah and Hedayati (2019) found the $LC_{50}$ 96 h of the pesticide butachlor was 0.785 mg/l and was less toxic for this species compared to *Rutilus kutum*. Ghani *et al*. (2019) found that a diet enriched with *Padina australis* alga partially improved serum immune indices of fish exposed to zinc oxide nanoparticles. Ghelichpour and Taheri Mirghaed (2019) studied the effects of 21 days exposure to the new pesticides lufenuron and flonicamid and found they induced stress and altered gill function and blood ionic homeostasis during saltwater exposure. Golpour *et al*. (2019) investigated the effect of the dietary alga *Padina australis* on the mucus resistance indices of fry exposed to silver nanoparticles, and found higher mucus protein content in fish treated at 1 and 2%, although there was no significant difference between treatments. Kamali *et al*. (2019) found carp skin mucus could be used as a biomarker for contaminants and toxins as di 2-ethyl hexyl phthalate, a widely used industrial plasticiser with estrogen-like properties, was detected using protein and amino acid profiles. Khosravi Katuli *et al*. (2019) showed that silver nitrate at low concentrations had destructive effects and, along with silver nanoparticles, almost identically changed immunity factors and oxidative stress. However, in the superoxide dismutase enzyme, an important antioxidant defense, these changes were slightly higher in fish exposed to silver nitrate. Meshkini and Rasooli Aghdam (2019) found no significant relationship between the content of the heavy metals copper, mercury and zinc with biometric indices (age, length, weight) and between muscle and liver tissues of wild and farmed carp. There was a significant relationship between carp sex and accumulation of zinc and mercury but not copper. The amount of mercury in farmed carp was higher than allowable standards. Mohebi Derakhsh *et al*. (2019) showed the effect of diclofenac, an anti-inflammatory drug that is a pollutant in wastewater, on the activity of anti-oxidant enzymes superoxide dismutase and catalase over time and with increasing concentrations. Mortazavi *et al*. (2019) examined juveniles for the disruptive effects as oestrogen mimics of 4-nonylphenol and bisphenol A and their mixture, and demonstrated induction of vitellogenin as a biomarker for screening aquatic ecosystems. Mortazavi and Hatami Manesh (2019) evaluated the health hazard of the heavy metals chromium, copper, lead and zinc in muscle tissue of fish from the Bashar River, and found no risk although the trend to increasing pollution was a concern. Naderi Farsani *et al*. (2019) monitored heavy metals (cadmium, copper, lead, nickel, zinc) in water, sediment and fish tissues in the Aras Dam. The heavy metals were more concentrated in sediment than fish tissues or water, muscle accumulation was highest in summer and lowest in winter, and levels in fish were less or slightly higher than global standards. Nourian *et al*. (2019) found that dietary vitamin C at 500 mg/kg had some beneficial effects against lead toxicity. Shahryari *et al*. (2019) investigated the effect of the water-borne flavonoid genistein on haematological parameters but found no toxic effects. Shamloofar and Hajimoradlou (2019) found a 96h $LC_{50}$ of 14.187 mg/l for juveniles exposed to the insecticide sevin and clinical symptoms and histopathology were detailed. Taleghani *et al*. (2019) showed that *Rosa damascena* extract at 2.5 and 5 g in 100 g commercial feed decreased the toxic effect of zinc on the liver.

Fakhri *et al*. (2020) measured the concentration of potentially toxic elements in fillet tissue of carp by the aid of a systematic review and meta-analysis and found the non-carcinogenic health risk through consumption was at a negligible level. Gharaei *et al*. (2020) found that the drug indomethacin (a non-steroidal anti-inflammatory) in the water could influence antioxidant status and health of carp. The $LC_{50}$ was 328.49 mg/l. Ghelichpour *et al*. (2020) studied the toxic effects of the pesticide lufenuron on juveniles and found a decrease in

plasma proteins, increased liver enzymes and liver damage, and the antioxidant system and thyroid hormones were affected. Haghighat *et al*. (2020) showed that titanium nanoparticles enhanced the toxicity of silver nanoparticles and emphasised the importance of considering the co-existence and interaction of nanoparticles in the environment. Johari *et al*. (2020) compared the dietary toxicity effects of two different copper compounds, copper oxide nanoparticles and ionic copper in juveniles and found enhanced toxicological responses after 21 days of dietary exposure, but the levels of most biochemical indices and tissue copper content decreased or returned to the control values after the recovery period. Kazemian and Bakhshi (2020) found zinc nanoparticles increased oxidative stress and had inappropriate effects on hepatic enzymes in koi. Madani *et al*. (2020) showed that sublethal doses of the pesticide glyphosate had significant deleterious effects on gill and testis structure, affecting oxygen uptake and reproduction. Mohebi Derakhsh *et al*. (2020) found that diclofenac-exposed fish had harmful histological alterations to the gills, kidney and liver. Movafagh Behnam *et al*. (2020) measured mercury and zinc in muscle of fish from Mahmoudabad to Nowshahr in the Caspian Sea basin and found high levels of zinc at 48.68 μg/g, and metal content of the bentho-pelagic carp generally was less than in predatory species such as *Sander lucioperca*. Rahmani Khanqahi *et al*. (2020) investigated the toxicity of the rice field herbicide bensulfuron methyl and found mortality increased with concentration and exposure duration and the lethal concentration decreased with increasing exposure duration. The $LC_{50}$ 96h was 1.62 g/l. Rezaei *et al*. (2020) found changes in haematology from chronic exposure to carbamazepine, a seizure medication found in aquatic environments as a micro-persistent pollutant. Rezaie Tavabe *et al*. (2020) examined the effects of multi-walled carbon nanotubes, used as absorbents in industry, on carp under laboratory conditions, finding a wide variety of deleterious results on growth, blood parameters and histopathology. Sahraei *et al*. (2020) showed that even small amounts (10-100 micrograms/gram of food) of iron and zinc nanoparticles caused changes in the intestine and brain. Taheri Mirghaed *et al*. (2020) showed that chronic exposure to the insecticide flonicamid ($LC_{50}$ 96h 4.3 mg/l) had serious effects on the gills and kidneys and caused ionic changes in the blood. Tasa *et al*. (2020) found that dietary aflatoxin $B_1$ contamination pathologically elevated digestive enzymes activity and intestinal lesions were exacerbated in fingerlings, while adding 4% rosemary and thyme powder to the diet ameliorated enzyme activity but not intestinal lesions. Tulaby Dezfuly *et al*. (2020) exposed juveniles to lead (0-120 mg/l) at varying salinities (0-0.4 g/l) and found that salinity did not affect haematological parameters but the $LC_{50}$ values decreased with increasing salinity. Bampoori *et al*. (2021) found the insecticide deltamethrin in sublethal amounts caused hyperaemia and oedema, hyperaemia of the gill arch, fusion of lamellae and hyperplasia in gills, nephritis, haemorrhage, hyaline casts, cell swelling in the kidney, and fat degeneration in the liver. Significant increases were found in the level of some serum enzymes in the blood.

*Diet:-*

Shir Mohammadi *et al*. (2003) found the addition of 3% citric acid to the diet improved carcass composition and provided better digestive tract conditions for microbial phytase without any positive effect on growth. Abdi *et al*. (2009) showed that a supplement of 0.2% of dietary nucleotide had positive effects on growth and proximate composition. Nickho *et al*. (2009), Nikkhoo *et al*. (2010) and Yousefian *et al*. (2010) examined the addition of 1.5-2.0 g/kg of aqualase, a yeast probiotic, to the feed of fingerlings and found positive effects on various growth factors and immune response and eliminated mortality in fish challenged with *Streptococcus iniae* bacteria.

Alishahi *et al*. (2010) found feeding *Aloe vera*, a succulent plant, enhanced immune responses and Alishahi *et al*. (2014) found the beneficial effects were dose-dependent. Baghfalaki *et al*. (2010) studied food habits of larvae and fingerlings in earthen ponds. Faghani Langaroudi (2010) studied the effects on juveniles of dietary probiotics (protexin and primalac) showing growth and final weight were higher, mortality and food conversion ratio were lower, and beneficial bacterial counts were increased. Mahmoudi *et al*. (2010) found that dietary nucleotides led to a significant increase in such blood biochemical parameters as glucose, total protein, albumin and triglyceride and in some haematological parameters, but not in all parameters. Malekinezhad *et al*. (2010) examined the use of liquorice plant extract to counter hepatotoxicity (induced with carbon tetrachloride) finding a protective effect attributed to antioxidant capacity. Faramarzi *et al*. (2011) found a reduction in cost of fish feed when sweet potato peels were incorporated. Kazerani and Shahsavani (2011) used a multi-enzyme feed supplement which proved ineffective in improving growth and feed conversion rates and even exerted negative effects with higher doses. Mohammadnejad Shamoushaki and Miraghazadeh (2011) found the use of zeolite in the diet improved growth but not survival. Zabihi *et al*. (2011) showed the useful effect of sodium selenite as a diet additive for carp fingerlings. Zabihi *et al*. (2011) examined the growth, feeding effects and body composition of fingerlings fed chicken slaughter wastes, essentially negative. Ebrahimi *et al*. (2012) studied the effects of a prebiotic, immunogen, on feed utilisation, body composition, immunity and resistance to *Aeromonas hydrophila* infection in fingerlings, a dosage of 1.0-1.5 g/kg being effective. Akrami *et al*. (2012) found that dietary supplementation with 1.5% prebiotic inulin improved growth performance and survival in juveniles. Assareh *et al*. (2012) recorded the effects of a starvation period on growth performance and survival of fingerlings, negative of course. Falahatkar *et al*. (2012) noted the addition of 0.2% nucleotides in the diet had a positive effect on growth and some biochemical parameters. Khajepour *et al.* (2012) compared juvenile diets involving crude protein, citric acid and microbial phytase. Mohammad Nejad Shamoushaki *et al*. (2012) balanced growth rate and optimal use of fish meal, finding that 7.5% body weight per day of meal gave maximum body weight and length in fingerlings. Noveirian and Nasrollahzadeh (2012) fed juvenile carp biogen probiotic which improved growth performance and feeding efficiency (optimum amount 0.3 g/100 g of diet). Peyghan *et al*. (2012) investigated dietary cholesterol used to increase the amount of sex hormones. Pourabasli *et al*. (2012) showed how the probiotic *Lactobacillus plantarum* had positive effects on various blood and serum parameters in fingerlings. Rahmani *et al*. (2012) added probiotic supplements in the diet from several species of *Bacillus*, resulting in better growth performance. Ramzani *et al*. (2012) successfully reared carp on a small scale in fibreglass tanks using an artificial diet, with water quality exposed to change. The conversion ratio was high but growth ratio was low. Sahandi *et al*. (2012) showed the growth enhancement effect of *Saccharomyces cerevisiae* yeast extract added to the diet of larvae in their first month of feeding. Sahandi *et al*. (2012) used probiotic bacilli (*Bacillus circulans* and *B. licheniformis*) directly inoculated to the rearing system which reduced culture risks through improved growth and health in fish fed *Artemia parthenogenetica*. Shamoushaki *et al*. (2012) studied management and optimisation of feeding frequency for juveniles. Akrami *et al*. (2013) found 1.0 g/kg of prebiotic mannan oligosaccharide and ß-1, 3-glucan improved growth performance index, survival, final production and body composition of juveniles over 45 days. Al-Hosseini and Akrami (2013) added 2.5% betaine (as betafin, modified sugar beet) in the diet of wild common carp and improved growth performance, feeding efficiency and resistance to environmental stress. Ali

Asghari *et al*. (2013) found elongating a starvation period decreased the compensation growth of fry. Aliasghari *et al*. (2013) found that blue light in tanks gave optimum growth of koi larvae, compared to green and red. Alipour and Avokhisemi (2013) studied the effectiveness of an aquaponic system on growth and survival enhancement of carp larvae. Plants (*Aloe vera* and *Foeniculum vulgare*) and shrimp (*Macrobrachium rosenbergii*) were included in the system. There were significant differences in carp body weight, body weight gain, specific growth factor and survival rate, and in some physico-chemical factors. Ghaderi Ramazi *et al*. (2013) showed how corn gluten meal was not a good alternative for fish meal in the juvenile carp diet. Ghasempour Dehaghani *et al*. (2013) studied the effects of dietary supplementation with biomin imbo synbiotic finding enhanced growth but no difference in survival, and that 1.5 g/kg showed the most gut probiotic replacement but bacterial colony counts decreased at day 75 by probiotic elimination in the diet after day 60. Javarian *et al*. (2013) found larvae fed yeast extract (*Saccharomyces cerevisiae*) showed improved growth parameters and increased resistance to stressors. Khodanazary *et al*. (2013) studied the effects of dietary zeolite and perlite supplementations on growth and nutrient utilisation and on some serum variables, a 5% level being useful as a new aquafeed ingredient. Mohammad Nejad Shamoushaki and Mazini (2013) studied starvation and compensatory growth and found use of the yeast *Saccharomyces cerevisiae* gave better growth after a starvation period. Nosratpur *et al*. (2013) found diets supplemented with 0.4-0.6% mannan oligosaccharide increased growth and nutrition efficiency in wild carp, but chemical analysis of body composition did not show any significant differences between treatments. Alishahi *et al*. (2014) used dietary chitosan derived from shrimp exoskeleton to stimulate immune resistance and resistance against bacteria. Baghaei Jezeh *et al*. (2014) studied the influence of supplemental barley and formulated dry feed, finding no differences in growth between formulated and a 50:50 mix of formulated and barley feed, higher levels of fat and ash in barley feed, and higher levels of protein in formulated feed. Bahrami Babaheydari *et al*. (2014) showed that adding wood betony extract (*Stachys lavandulifolia*) at 2-4% (g per 100 g diet) improved growth and non-specific immunity. Bakhshi *et al*. (2014) found that fish fed a 50% commercial diet and biofloc products (which balance carbon and nitrogen in the aquaculture system) showed higher weight gain and decreased ammonia, nitrite and nitrate despite no water exchange in intensive farming. Delavariyan *et al*. (2014) investigated replacing fish oil with vegetable oil as a diet supplement, the best treatment being 50% soybean oil and 50% palm oil according to growth, nutrition and survival indicators. Ebrahimi *et al*. (2014) found that an increase in a starvation period followed by compensatory growth causes a decrease in protein, fat, ash, fibre, carcass quality and survival, and an increase in ash carcass in fry. Esmaeili Rad *et al*. (2014) extracted chitosan from white leg shrimps (*Litopenaeus vannamei*) and fed it to carp, finding a 1% diet improved growth indices but no diet had a significant impact on haematological parameters. Hoseinifar *et al*. (2014) used fructo-oligosaccharides in the diet of fry as a prebiotic, finding positive effects on white blood cells and respiratory burst activity, increased levels of gut microbiota, and increased survival rate and stress resistance, while other factors showed no change. Hosseini *et al*. (2014) examined l-lysine for its effects on growth, body composition and survival in juveniles but did not recommend it. Karimi *et al*. (2014) found fingerlings responding to short periods of fasting by an increased appetite and growth rate to compensate for weight loss rather than improved feed efficiency and utilisation. Mooraki *et al*. (2014) found that 0.5% parsley (*Petroselinum sativum*) could be used in koi feed as a good growth stimulator. Nasrolahzadeh and Alaf Navirian (2014) used *Phragmites australis* reed roots as a

supplementary food, the best growth and feeding efficiency being at the 6% and 9% levels in the diet. Ramezani (2014) and Ramzani *et al*. (2014) formulated a food pellet for grow-out carp which was an improvement over a commercial pellet, showing greater weight gain and feed conversion ratio and greater stability in water. Sharifzadeh *et al*. (2014) found the optimal levels of vitamins E and $B_2$ (riboflavin) in fish meal for fingerlings were 80 mg/kg and 7 mg/kg.

Ahmadivand *et al*. (2015) investigated the effects of dietary selenium nanoparticles and organic selenium (selemax) on growth of fingerlings, finding the former had more effect than the latter. Asadian *et al*. (2015) found that fingerlings fed a multi-strain probiotic at 75 mg/kg showed improved growth and feed conversion rates. Bahrami Babaheydari *et al*. (2015) studied the effect of dietary wood betony (*Stachys lavandulifolia*) extract which showed improved growth and some immunity characteristics, and decreases in triglycerides and cholesterol. Ghobadi *et al*. (2015) examined the use of the dietary probiotic bactocell (containing lactic acid bacteria) and found a supplement of 0.2 g/kg had positive effects on growth and proximate composition. Haghipoor *et al*. (2015) found that fry fed isomaltooligosaccharide as a prebiotic showed no growth changes or survival from a control but salinity stress resistance showed an increase and mortality was lower. Hoseinifar *et al*. (2015) showed that dietary date palm fruit extract improved growth performance of fry and increased skin mucosal immunity but immune-related gene expressions were not remarkably affected. Imanpoor *et al*. (2015) showed that the addition of the herbal supplement sangrovit to the diet of fingerlings improved growth performance and blood biochemical parameters but not survival or tolerance to salinity stress. Keramat Amirkolaie and Rostami (2015) found that dietary supplementation with the prebiotic immunogen at 5 g/kg improved fingerling growth performance and feed utilisation, and had beneficial effects on gut microflora which improved digestive performance. Imanpour *et al*. (2015) examined the effect of primalac probiotic on growth indices, blood biochemical parameters, survival, and resistance to salinity stress in fingerlings, showing positive effects in all but no difference in survival. Loukhi *et al*. (2015) used a treatment diet of 1.0-1.5% nucleotides over eight weeks and found significant increase in relative food eaten but not in other growth parameters such as weight gain, feed conversion ratio and specific growth. There was a positive effect on haematological parameters such as white and red blood cells and haemoglobin. Survival rate also increased. Mahmoudian *et al*. (2015) showed that adding the dietary prebiotic alphamune (a yeast extract) at 0.5 g/kg improved growth parameters and nutrient efficiency but the probiotic protexin did not. Minabi *et al*. (2015) demonstrated the effective replacement of 60% of fish oil with canola oil in the diet of juveniles. Mooraki and Dadgar (2015) used parsley (*Petroselinum sativum*) in the diet of koi finding better growth, food conversion ratio and survival rate. Naderi Farsani *et al*. (2015) found that 0.5% broccoli in the diet had positive effects on haematological and biochemical parameters, possibly on some growth indices, and on the immune system and health of the fish. Ouraji *et al*. (2015) studied the use of *Azolla* (a highly productive aquatic fern) meal on growth performance of fingerlings with additions up to 15% having no negative effect but growth was reduced significantly above this level. Pirali Zefrei *et al*. (2015) fed carp highly-nutritious, dried green hulls of pistachio (*Pistacia vera*) and levels up to 0.5% showed growth improvement while higher levels had a negative effect. Purabbasali *et al*. (2015) studied the positive effects of dietary probiotic yeast and isolated sturgeon (*Huso huso*) gut *Bacillus* species on larval survival and body extract. Roohi *et al*. (2015) examined the use of fenugreek seed meal on growth performance and blood indices, finding it to be a beneficial dietary supplement. Roohi

*et al*. (2015) similarly evaluated caraway seeds meal, also beneficial. Soleimany *et al*. (2015) examined the effects of marshmallow extract (*Althaea officinalis*) on hepatopancreatic enzymes, increasing pancreatic a-amylase, decreasing lipase but not affecting trypsin levels. Taati and Noei Taadoli (2015) found that an herbal diet additive including carvacrol, anethole and limonene at 2 g/kg was effective in increasing growth performance and some haematological and immune parameters in farmed fingerlings. Adelian *et al*. (2016a) utilised kemin multi-enzyme, a commercial preparation, in the diet and found condition factor unchanged but weight gain, specific growth rate and feed conversion ratio improved as did calcium enzyme levels but no other blood factors. Adelian *et al*. (2016b) studied the use of the multi-enzyme preparation natuzyme in the diet to increase protein intake and improve growth factors. Enzyme levels of 250 and 500 mg/kg influenced weight gain, specific growth rate, feed conversion ratio, weight growth percent and protein efficiency ratio but had no significant effect on blood biochemical parameters. Azimi *et al*. (2016) studied the effect on growth performance in fingerlings and water quality in tanks of different ratios of carbon and nitrogen in a biofloc system (which degrades organic wastes by using microorganisms and produces flocculation), finding a carbon/nitrogen ratio of 1:15 had a positive impact on water quality, improved food consumption and growth performance, as well as reducing the amount of water consumption in the system. Baesi *et al*. (2016) showed that various growth and nutritional parameters improved in young fed the probiotic *Lactobacillus*. Bahremand *et al*. (2016, 2017) showed that, while 2 g/kg of prebiotic immunogen fed to juvenile koi carp did not improve growth performance after starvation, results were better than fish receiving no prebiotic and in terms of immunity. Ramezani (2016) evaluated the impact of a dietary herbal appetiser on the growth performance of growth-out carp but concluded it could not improve growth, feed conversion rate and weight gain. Bakhshi *et al*. (2016) evaluated the application of biofloc technology in rearing fingerlings in intensive culture, finding an increased growth performance and decreased water exchange via quality improvement. Banaee *et al*. (2016) examined the effect of dietary mint extract (*Mentha longifolia*) on blood biochemistry and growth performance of juveniles and found cell toxicity and some growth factors improved. Banaee *et al*. (2016) examined the toxicity and safety of marshmallow extract (*Althaea officinalis*) used as a naturopathic medicine and found dietary supplementation at 2.5 and 5 g had no side effects. Falamarzi *et al*. (2016) studied the effects of different levels of meal and alcoholic extract of alfalfa (*Medicago sativa*) and found 4% extract and 9% alfalfa meal gave the best growth, nutrition and carcass quality. Hoseinifar (2016) investigated the effects of different levels of two prebiotics, inulin and oligofructose, with different degrees of polymerization, on the intestinal microbiota of larvae, finding these prebiotics could be used for modulation of carp intestinal microbiota toward beneficial bacterial communities, and that administration of the prebiotic with the lower degree of polymerisation was more efficient for modulation of intestinal microbiota and elevation of lactic acid bacteria levels. Hosseini *et al*. (2016) added *Lactobacillus plantarum* and *L. bulgaricus* bacteria isolated from the intestine of *Arabibarbus grypus* to the diet of carp, causing an increase of beneficial microflora and improving growth performance. Jafari *et al*. (2016) added calcium chloride and the amino acid glutamine to the diet and found these feed additives increased weight gain, body weight percentage and lowered the food conversion ratio. Javaheri Baboli *et al*. (2016) demonstrated that the prebiotic immunoster was effective on growth and nutrition performance in fingerlings, but not survival rate, *Lactobacillus* count and body composition. Koliaee *et al*. (2016) used the probiotic bacterium *Bacillus subtilis* extracted from carp intestine to feed young fish at a rate of $1 \times 10^6$

CFU/ml per kg diet (CFU = colony-forming unit or number of viable cells), this having positive effects on growth parameters and nutrition indices. Mohammadi *et al*. (2016) studied the effects of dietary niacin on the gut and liver histology and some liver enzymes of juveniles and found that 90 mg/kg in the diet had a beneficial result. Mohammadi Sarpiri *et al*. (2016) showed increased levels of copper and zinc in the diet changed serum parameters related to bone metabolism and could affect bone formation to some extent. Nazari *et al*. (2016) investigated replacement of animal with plant protein for decreasing food costs in aquaculture, comparing various phytase-producing bacteria for their probiotic potential. Rahmdel *et al*. (2016, 2018) evaluated the effects of fish meal replacement with sunflower meal, finding up to 75% replacement in fingerling diet had no negative impacts on growth, body composition, and haematological or plasma biochemical indices. Ramezani *et al*. (2016) investigated the use of a commercial dietary herbal appetiser on growth, feed conversion rate and weight gain but found no improvement. Safari *et al*. (2016) found up-regulation of growth and health related genes in fish fed ferula (*Ferula assafoetida*). Same *et al*. (2016) studied the effect of chitosan (derived from crustacean exoskeletons) on fry growth, survival, haematological parameters and resistance to salinity stress, finding a 1% supplement of this prebiotic had a positive effect on growth performance and some blood parameters. Taati *et al*. (2016) determined that vitamin E at 200 mg/kg in the diet enhanced growth performance and nutrition efficiency, improved blood indices, and supported cell immunity in fingerlings. Baesi *et al*. (2017) demonstrated that the commercial probiotic *Lactobacillus acidophilus* used in the diet improved the nutritional value of carp. Bahadori Birgani and Chehelmal Dezfulnezhad (2017) studied the effects of extracts of myrtle, *Myrtus communis*, in the diet on growth, survival and the blood and immune systems, finding increases in growth, survival, and certain blood and serum parameters. Dadashi *et al*. (2017) studied various effects of adding tomato pulp, supplemented with an enzyme complex, to the diet with 10% pulp, for example, showing maximum growth and feed conversion ratio while the added enzyme did not influence body composition. Eslamizadeh and Qaeni (2017) studied the effect of biocompatible compost supplementation on growth, specific growth factor (both increased) and feeding conversion ratio (decreased). Forouhar Vajargah *et al*. (2017) found that using the dietary multi-enzyme natuzyme increased growth indices but higher doses had elevated phosphorus and nitrogen levels, affecting the immune system and increasing the mortality rate during exposure to the pesticide abamectin, and so the multi-enzyme was not recommended in such conditions. Ghasemi *et al*. (2017) found 0.5-2.0% dietary turmeric (*Curcuma longa*) remarkably decreased liver and kidney damage due to copper sulphate challenge. Copper sulphate is widely used in warmwater fish ponds to control snails and aquatic plants. Hosseini Mashhadi *et al*. (2017) determined the optimum level of ascorbic acid in the diet to improve growth performance of fingerlings was 300 mg/kg, although survival and condition factor were not affected. Javid Rahmdel *et al*. (2017) found it was possible to replace fishmeal with sunflower meal in up to 75% of the diet of fingerlings without negative impacts on growth performance, feed efficiency and body composition. Mehrabi *et al*. (2017) examined the effects of immunowall prebiotic (a yeast extract rich in β-glucans and mannan oligosaccharides promoting gut microflora) and primalac probiotic, alone or as mixtures, on growth, survival, body composition, and haematology and immune system stimulation of fry, finding positive effects for primalac, and to a lesser extent, immunowall. Mohammadi-Zadeh Khoshroo *et al*. (2017) showed that extremely low-frequency electromagnetic fields (50-Hz) enhanced growth performance and survival rate of fingerlings. Naderi Farsani *et al*. (2017) showed that 1% broccoli powder (*Brassica oleracea* var.

*gemmifera*) in the diet increased the total protein in mucus and may boost the immune system. Nasipour *et al*. (2017) examined the effect of a synbiotic (combined prebiotic and probiotic, immunogen and *Lactobacillus casei*) on gastrointestinal enzymes, finding an increase in activity leading to digestive efficiency and raised growth. Saberyan Juybari *et al*. (2017) measured the effect of different levels of the prebiotic A-max in the diet and found no beneficial growth, survival and body composition results in juveniles. Safari *et al*. (2017) supplemented the diet of juveniles with sodium propionate and found an improvement in immune parameters. Sanchooli *et al*. (2017) studied restricting and then re-feeding fingerlings with protein, where a two-week restriction showed highest final weight, body weight increase, percentage of body weight gain, feed conversion efficiency, feed conversion ratio and specific growth rate, for example. Soltani *et al*. (2017) used the probiotic *Lactobacillus plantarum* in feed to improve growth variables and immunophysiological responses and also to increase disease resistance to septicaemia caused by *Aeromonas* bacteria. Taheri *et al*. (2017) found using zinc oxide nanoparticles as a dietary supplement had no side effects at 5 mg/kg feed. Abbasi Ghadikolaei *et al*. (2018) studied the use of ginger, *Zingiber officinale*, powder in commercial diet and found some improved growth indices. Adeli *et al*. (2018) found one week of food and two weeks starvation gave the best carcass analysis (more protein and less fat). Adineh *et al*. (2018) used yucca plant extract (*Yucca schidigera*) to increase intestinal flora activity and improve growth performance, body composition, and culture water quality in carp aquaculture. Ahmadifar *et al*. (2018) supplemented the diet with *Zataria multiflora* (Persian or Shirazi thyme) and *Satureja khuzistanica* (marzeh khuzistani, family Lamiaceae) powder and found that adding 13 g of herbal supplement per kg of carp improved performance growth, nutrition and biochemical indices. Alishahi *et al*. (2018) investigated the effects of two probiotics, *Lactobacillus plantarum* and *L. bulgaricus*, on juveniles and concluded the latter promoted growth indices and intestinal lactic acid bacterial proportions. Ansarifard *et al*. (2018) found that adding 5-10% *Arthrospira platensis*, a cyanobacterium (the dried biomass is known as spirulina), in the diet had positive effects on the growth rate, pigmentation and digestive and liver enzymes of koi. Bahrekazemi and Asadi (2018) showed that adding the prebiotic mito to the diet at 0.2% after one week of starvation affected compensatory growth but did not exceed the control group. However, the prebiotic significantly elevated the haematological status of the fish. Heidari *et al*. (2018) incorporated stevia (*Stevia rebaudiana*) extract in the juvenile diet at a concentration of 2,000 p.p.m. and this had a significant effect, enhancing growth parameters and chemical properties. Hoseinifar *et al*. (2018) showed that common guava leaf powder (*Psidium guajava*) in the diet of fingerlings improved growth performance and had beneficial immunomodulatory effects. Hosseinifar *et al*. (2018) found that dietary *Lactobacillus acidophilus* increased immunity through an increase in the relative expression of lysozyme, important in prevention of bacterial infections. Iry *et al*. (2018) found that the prebiotic A-Max ultra, a yeast culture, improved growth parameters, survival rate, feed utilisation and resistance time to a challenge test in larvae. Karimi *et al*. (2018) used the dietary multi-enzyme apsozyme and the probiotic *Pediococcus acidilactici* to enhance growth and blood biochemistry of juveniles. Karimi Pashaki *et al*. (2018) showed that diets of fingerlings containing an aqueous-alcoholic extract of olive leaf (*Olea europea*) at 1 and 5 g/kg resulted in a reduction in food conversion ratio and improvement of some blood and immune parameters. Karimi Pashkai *et al*. (2018) showed that garlic extract at 5 g/kg as a dietary supplement improved some blood parameters, immunity and growth of fingerlings. Khaleghi *et al*. (2018) combined the food supplements comprising bacteria (*Pediococcus acidilactici*) and powdered

mushrooms (*Agaricus bisporus*) to combat exposure to nano-silver as shown by skin mucosal indices. Khorshidi *et al*. (2018) found that dietary curcumin showed a protective effect against the toxicity of silver nanoparticles (pollutants of aquatic ecosystems) to gut microbiota. Mohammadi *et al*. (2018) found that dietary supplementation for juveniles with 0.5% date palm seed extract improved body composition and antioxidant defense. Mohammadi *et al*. (2018) used 2,000 IU/kg of phytase and 20 g/kg of wheat bran in the fry diet and improved growth indices and phosphorus absorption rate. Phytase is an enzyme that catalyses the hydrolysis of phytic acid, an indigestible, organic form of phosphorus found in grains and oil seeds. Nasrabadi *et al*. (2018) studied the effect of dietary carrot pomace and molasses on total bacterial count and intestine histology in juveniles in a biofloc system, finding higher bacterial counts in the gut and water and alterations of gut villi length, club cells and leucocytes. Pashaki *et al*. (2018) showed that diets of fingerlings containing an aqueous-alcoholic extract of olive leaf (*Olea europea*) at 1 and 5 g/kg resulted in a reduction in food conversion ratio and improvement of some blood and immune parameters, but higher levels caused cytotoxicity and alterations in oxidative biomarkers. Safari and Sarkheil (2018) evaluated the effects of adding edible mushroom powder, *Pleurotus eryngii*, to the diet of koi carp fingerlings for 63 days on haematological parameters, serum immune responses, skin mucus, bactericidal activity, stress resistance, growth performance and digestive enzyme activities and found levels of 1.5 and 2% improved the selected humoral innate immune responses, bactericidal activity of skin mucus, and growth performance. Sepehrfar *et al*. (2018) showed that administration of dietary probiotic *Pediococcus acidilactici* and prebiotic *Agaricus bisporus* improved some blood parameters of juveniles. Tasa *et al*. (2018) investigated the protective efficiency of rosemary and thyme powder against feed for fingerlings contaminated with the mycotoxin aflotaxin B1, finding mitigation of the deteriorative effect on intestinal protease and amylase activities along with red blood cell count, haemoglobin content, and neutrophils and leucocytes. Tataati and Salehi (2018) found that the multi-enzymes natuzyme and combo added to food improved haematological and biochemical parameters of fingerlings. Vajargah *et al*. (2018) found that kemin multi-enzyme increased fish growth but, because it affected intestinal absorption, the toxicity of the pesticide abamectin increased as did mortality rate. Varasteh *et al*. (2018) studied the effect of water hyacinth plant (*Eichhornia crassipes*) in an aquaponic system on changes in growth indices, immune factors and hepatic enzymes of koi, finding the plant affected growth factors and blood indices, which could be due to the effect of this plant as an agent for enhancing immune stimulation. Vaziriyan *et al*. (2018) found diets containing the fungal contaminants aflatoxins resulted in toxic effects and changes in plasma biochemical indices. Yavar *et al*. (2018) investigated different levels of water oxidation reduction potential on carp and found, in general, that levels in the 200-300 mv range did not have a negative effect on fish and their mortality but improved water quality indices. Zargaran Hoseini and Chelemal Dezfulnejad (2018) fed juvenile carp with 10% banana peel powder and found significant effects on specific growth rate and protein efficiency ratio. Fish fed with the powder at 5% of diet had the highest value of fat and carbohydrates. The highest value of protein, ash and moisture was recorded for fish fed at 15%. Ahmadifar *et al*. (2019) studied the effect of persimmon leaf extract (*Diospyros kaki*) as feed additive on some blood parameters and non-specific immune responses in juveniles and found it could be used as a nutritional supplement to strengthen safety indicators. Alinezhad (2019) found that dry extracts of *Achillea millefolium* (yarrow), *Echinacea purpurea* (purple coneflower) and *Mentha piperita* (peppermint) in the juvenile diet all improved immune response and haematological parameters

with the latter at a lower concentration being more efficient. Amiri *et al*. (2019) showed that sugar beet (*Beta vulgaris*) in the diet had a positive effect on the survival and feed conversion indices, and increased specific growth rate and hepatosomatic and viscerosomatic indices. Bahrami Sheikh Sarmast *et al*. (2019) found fingerlings fed diets supplemented with 2% formic acid showed significant increases in mucus and serum lysozyme. Barghaman *et al*. (2019) showed that adding 2% probiotic *Lactococcus lactis* and 1% chitin to the diet improved white blood cell count and the intestinal bacterial colony. Basseri Arghavani *et al*. (2019) supplemented the diet with EDTA (ethylenediaminetetraacetic acid), a chelating agent, and found varying concentrations reduced a suite of heavy metal loads. Beigichamforest *et al*. (2019) found dietary orange peel powder had no significant differences in growth indices compared to a control group. Beygi *et al*. (2019) investigated the effects of different levels of dietary beet molasses on mucosal immunity parameters and serum biochemical parameters in juveniles, finding the amount of mucus solution increased, the highest level being with 2% molasses, alkaline phosphatase mucus increased at 1%, immunoglobulin did not change, soluble protein and alkaline phosphatase activity in blood serum increased, and the amount of blood serum glucose increased. Beygi *et al*. (2019) found red blood cells and mean corpuscular haemoglobin concentration increased with 2% beet molasses in the diet, but not white blood cells. Farzi *et al*. (2019) used 200 mg/kg of commercial XTRACT in the fry diet and generally increased and improved growth and the survival index. Hoseini *et al*. (2019) showed 0.5% dietary arginine (an amino acid) lowered mortality against ammonia toxicity, detoxifying ammonia by ureagenesis and glutamine synthesis, and also had anti-stress, antioxidant and anti-anemic benefits. Hoseini *et al*. (2019a) found dietary arginine at deficient or surplus levels significantly impaired growth performance and health conditions and surplus dietary arginine level had no benefit on the fish growth and health under a high stocking density condition. Hoseini *et al*. (2019c) showed dietary myrcene (a natural organic hydrocarbon) at 0.5% and menthol at 0.25% levels were effective in reducing the adverse effects of ammonia, these effects seemingly related to the compound’s antioxidant effects, which mitigated ammonia-induced tissue damage and anemia. Hoseinifar *et al*. (2019) demonstrated that dietary jujube (*Ziziphus jujube*) fruit extract was potentially useful on skin mucosal immunity and growth performance of fingerlings. Hoseinzadeh and Bahrekazemi (2019) found β-glucan could be used as a growth and immunity stimulant for fingerlings compared to lactoferrin and *Nigella sativa* (fennel flower). Hosseini Shekarabi *et al*. (2019) found that a commercial organic acids mixture added to the diet of juveniles at 3% was a growth promoter and had a positive effect on growth performance, survival rate and carcass quality. Inanloo *et al*. (2019) compared diets containing the bacteria *Lactobacillus acidophilus* and *Pediococcus pentosaceus* and found positive effects on growth, and on haematological and immunological parameters in juveniles using these probiotics. Kamali-Sanzighi *et al*. (2019) found that a dietary 10% date waste meal (*Phoenix dactylifera*) could be used as a substitute for other plant sources in the diet of fingerlings, improving growth, resistance to acidity and thermal stress, and blood variables. Karimi *et al*. (2019) administered the dietary prebiotic raffinose to fingerlings but this had no effect on growth parameters, although 2 or 4 g/kg was recommended for elevation of some mucosal immune parameters. Kharasaninejad *et al*. (2019) found that natuzyme plus (a commercial multi-enzyme) fed at 1.5 g/kg improved growth performance and feed efficiency in fingerlings. Kiapasha *et al*. (2019) used olive pomace as a dietary replacement in juveniles and found positive effects at a 6% level on growth performance and blood factors. Mahmoudi Khoshdarehgi *et al*. (2019) determined the appropriate level of protein in fry diet in a biofloc

system, finding a decrease from 35% to 27% had no effect on survival, growth, feed conversion ratio and some parameters of blood and serum biochemistry, and so the biofloc system was shown to help in protein feeding and physiological health. Maktabi *et al*. (2019) evaluated the effects of formic acid, potassium di format and formic acid nano-chitosan solution applications on different growth factors and body composition of fingerlings, recommending 0.25% formic acid nano-chitosan solution in common diets. Masoomi and Vazirzadeh (2019) studied the probiotic effects of natural immunostimulants, *Pediococcus acidilactici* and *Saccharomyces cerevisiae*, but found no statistically significant changes compared to a control group. Mohammad Nejad *et al*. (2019) showed that the addition of 400 mg/kg of each of vitamins C and E to the diet provided the best growth and survival. Mohiseni *et al*. (2019) compared the effects of dietary Persian thyme (*Zataria multiflora*) and vitamin E, individually and combined, on growth and biochemical parameters, finding 1% thyme increased growth performance with no harmful effects on plasma biochemical parameters, positive effects were more than with vitamin E, and vitamin E and thyme were not superior to thyme alone. Moradi Sogholmechi *et al*. (2019) found that dietary *Lactobacillus* probiotic decreased the adverse effects of nano-silver on immune function. Mousavi *et al*. (2019) supplemented the juvenile diet with 2% cumin extract (*Cuminum cyminum*) and improved such growth parameters as weight gain, daily growth rate and specific growth rate. Panahi Sahebi *et al*. (2019) showed that the addition of 0.1% immunowall (a prebiotic) and 0.15% primalac (a probiotic) in the juvenile diet had positive effects on growth, feeding and haematological indicators. Rajabiesterabadi *et al*. (2019) found dietary olive leaf extract had no influence on juvenile growth performance, but modulated gene expression of antioxidant enzymes and attenuated oxidative stress after eight weeks and Rajabiesterabadi *et al*. (2020) suggested that 1 g/kg of the extract in the diet may improve fish health and reduce the adverse effects of ammonia toxicity. Sarhadi *et al*. (2019) supplemented the diet with *Artemisia annua* (sweet wormwood) extract and found an improved fish health status including growth and blood parameters but no effect on liver enzymes. Sheikh Veisi *et al*. (2019) fed fry the probiotic *Lactobacillus casei* and studied growth and carcass composition when affected by iron nanoparticles (in the abstract, silver nanoparticles in the title, original paper not seen). The nanoparticles tended to neutralise the probiotic effect. Taheri Mirghaed and Hoseinifar *et al*. (2019) showed that a combination of the probiotic bacterium *Pediococcus acidilactici* and the prebiotic trisaccharide raffinose in the diet of juveniles improved immunological responses. Taheri Mirghaed *et al*. (2019) found dietary 1,8-cineole (eucalyptol, a compound of plant essential oils) at 0.5% suppressed stress response and oxidative stress and augmented thyroid hormone levels, as well as mitigating adverse effects of ammonia toxicity on serum $T_3$. Yousefi *et al*. (2019) found dietary rosemary leaf powder at 2-3% promoted growth performance, enhanced antioxidant and immunological parameters, and mitigated the negative effects of crowding stress in fingerlings.

Ahmadifar *et al*. (2020) revealed that the microbe *Pediococcus pentosaceus* was useful as a beneficial probiotic to improve the growth performance, digestive enzymes activity, elevation of heterotrophic aerobic bacteria, antibacterial activity against *Aeromonas hydrophila*, and haemato-immunological responses. Ahmadifar *et al*. (2020) used grape seed extract (*Vitis vinifera*) in the diet to reduce the adverse effects of chemical preservatives and found an increase in digestive enzyme activity and a healthy liver and intestinal structure. Ansarifard *et al*. (2020) found inclusion of 10% of the cynaobacterium *Arthrospira platensis* in the diet had a significant positive effect on the antioxidant defense mechanism, liver enzyme

activities and growth rates of koi. Asgharzadeh and Taati (2020) showed that acidifier supplementation in the diet could promote growth performance and improve some haematological and immune indices. Baghaei *et al*. (2020) determined that final body weight, feed conversion ratio and hepatosomatic index but not weight gain, specific growth rate and viscerosomatic index showed significant differences in fish fed dietary choline and lipid, the suitable level being 500 mg/kg of choline at 5% lipid. The biochemical composition of fillets was not affected. Bahrekazemi *et al*. (2020) found that intermittent feeding of the prebiotic mito at three-day intervals could be used instead of continuous feeding. Bahrekazemi and Qasemzadeh (2020) showed that while increased copper sulphate used as an algaecide in fish farms can affect the growth efficiency, nutrition and survival of carp, especially at 27°C, pre-treatment with calcium carbonate can significantly reduce these negative effects. Bakht Azad *et al*. (2020) added lysozyme to the diet of breeding stock at 1.0 and 1.5 g/kg where it had a beneficial effect in improving blood and biochemical parameters of the serum and in growth. Fazelan *et al*. (2020) showed that dietary ginger (*Zingiber officinale*) at 10 g/kg was beneficial in suppressing stress, oxidative stress and immunosuppression caused by high stocking density. Fazelan *et al*. (2020) also found that 1% dietary eucalyptol, an organic compound, mitigated oxidative stress and inflammation when administered for two weeks prior to copper sulphate treatments as disinfectant on fish farms. Gholi Tabar *et al*. (2020) studied the use of dietary thyme (*Thymus vulgaris*) extract in juveniles and found no effect on growth performance and haematological parameters in a salinity stress situation. Gholizadeh *et al*. (2020) investigated the addition of different concentrations of zero-capacity iron nanoparticles to the diet and found a concentration of 150 mg/kg was most effective in terms of growth while carcass quality and biochemical characteristics of blood showed varying results with differing concentrations. Golpoor *et al*. (2020) showed the effect of differing treatments with the alga *Padina australis* extract on growth indices was not significantly different. Hajirezaee *et al*. (2020) supplemented the diet with vitamin C and found that 500-1,000 mg/kg effectively prevented oxidative stress and undesirable effects of titanium oxide nanoparticles. Harsij *et al*. (2020) found that adding sodium butyrate, a known fish growth booster, to the diet of fingerlings did not affect growth and blood factors but the white blood cell count decreased when levels were 0.25% and 1%. Hedayati *et al*. (2020) investigated the effects of varying levels of dietary fermented *Aspergillus oryzae* on fry and found no significant differences between growth performance parameters with test and control diets and also with haematological parameters, but respiratory burst activity was meaningfully higher and the fungus modulated immune response. Heshmatfar *et al*. (2020) combined the probiotic *Pediococcus acidilactici* and formic acid in the diet for improved final weight and weight gain and resistance to salinity in fingerlings. Jafari *et al*. (2020) used 2% of the amino acid L-arginine as a dietary supplement to increase the weight of fingerlings and to increase resistance and survival to salinity stress. Jafarinejad *et al*. (2020) showed that dietary ginger (*Zingiber officinale*) improved growth performance, health status and antioxidant status. Jahazi *et al*. (2020) found beneficial effects for dietary polyphenols on growth performance, immune parameters and antioxidant defence in juveniles. Kalantari *et al*. (2020) examined the effect of dietary kiwi (*Actinidia* sp.) fruit peel powder on growth performance, carcass composition and digestibility and found no significant differences for most while the highest amount of dry matter digestibility was observed in 3-7% treatments. Kanaani *et al*. (2020) found adding sodium propionate and the probiotic *Pediococcus acidilactici* to the diet of young carp improved weight gain, specific growth rate and food conversion factor, as well as the

expression of some growth-related genes. Karimi *et al*. (2020) tested the effects of dietary raffinose on skin mucus immune parameters and protein profile, serum non-specific immune factors and gut immune genes and found 1.0 or 2.0 g/kg could promote immune competence and health indices. Karimi Pashaki *et al*. (2020) indicated that the addition of garlic extract (*Allium sativum*, especially at 5 g/kg) to the diet led to a higher immunity and survival rate of carp exposed to the highly lethal virus spring viremia of carp. Khosravi Najafabadi *et al*. (2020) used A-max ultra and liquid celmanax prebiotics inoculated into the water system of carp reared in a biofloc system and found positive effects on water quality parameters, and on growth performance, feeding efficiency and carcass composition of fingerlings. Maleki *et al*. (2020) showed growth indices, including the final weight, growth rate, specific growth rate and body weight gain, in a control and treatment with two days a week of starvation were significantly different, and the carp had the physiological adjustment ability to short-term starvation and a re-feeding period. Mallahi *et al*. (2020) fed carp with probiotics (bactocel bacteria and button mushrooms) and a synbiotic and found improved resistance performance to exposure to silver nanoparticles. Minabi *et al*. (2020) found a C/N ratio (carbon to nitrogen) of 19 with molasses as the carbon source in a biofloc system improved water quality, growth and feeding performance of cultured carp. Mohammadian *et al*. (2020) supplemented the fingerling diet with digetosterome, a mixture of phytogenic essential oils, and found a positive effect on growth performances without any negative effect on the liver and antioxidant enzymes. Mohammadrezaei (2020) found the use of spirulina (*Arthrospira platensis*, a cyanobacterium) in the diet of fingerlings at a level of 5%, improved growth performance and reduced food wastes while clove powder was less effective. Molaee Ghasemi *et al*. (2020) showed that potassium sorbate at 1% in the diet had beneficial effects on growth-related genes expression and could be used as a growth stimulant. Nekoubin *et al*. (2020) evaluated the effects of apple cider vinegar on growth performance and non-specific immune parameters (alkaline phosphatase, lysozyme and total protein) in fingerlings, finding no growth differences but improvement in skin mucus lysozyme activity and total protein, and concluding this vinegar could be a good candidate for antibiotic replacement. Niki Maleki *et al*. (2020) found a suitable effect of combined administration of the prebiotic Amax and probiotic *Lactobacillus casei*, especially on growth indices. Noori *et al*. (2020) found pre-treatment with 0.05 g/kg of dietary polyphenol supplementation had positive physiological effects on fish exposed to silver nanoparticles. Paray *et al*. (2020) studied the effects of dietary oak (*Quercus castaneifolia*) leaf extract and found at 1-2 g/kg antioxidant and immune systems were stimulated without affecting fish growth performance and the extract was partially beneficial in reducing crowding stress. Pourabasali and Ghobadi (2020) indicated that the simultaneous use of *Bacillus* and yeast probiotics in diet of carp larvae, isolated from the gastrointestinal tract of beluga sturgeon (*Huso huso*), had positive and significant effects on improving growth parameters, biochemical compounds of body extract, survival rate and resistance against environmental stresses, especially at the level of 4.5 x $10^6$ CFU/g (colony-forming unit or number of viable cells). Rajabiesterabadi *et al*. (2020) found dietary turmeric administration at 10 g/kg significantly mitigated/inhibited copper-induced negative effects, apparently due to the augmentation of the antioxidant defence. Saberifar *et al*. (2020) found AMP deaminase activity in carp muscle increased following nitrite intoxication and this activity could be an adaptive response to hypoxic conditions caused by the intoxication. Safari *et al*. (2020) administered non-alcoholic beer concentrate to the diet of juveniles resulting in improved immunity and growth. Sahli *et al*. (2020) showed low molecular weight sodium alginate in the diet gave a significant increase

in the total protein content of mucus and stimulated and increased immunity. Sahraei *et al*. (2020) found that adding iron and zinc nanoparticles in the diet may play an important role in increasing and improving growth factors. Sheikhveisi *et al*. (2020) investigated the protective effect of molasses pre-treatment on serum immunity indices of juveniles exposed to iron nanoparticles and found, in the combination of nano-iron and molasses, the amount of ALP and AST (hepatic enzymes) indices significantly decreased, meaning molasses in combination with nano-iron could improve the nano-iron supplementation but, in the remaining indices, molasses could not neutralize the increased effect of nano-iron. Taheri Mirghaed *et al*. (2020) showed hepatoprotective effects and growth stimulation of dietary artemisia (*Artemisia annua*) leaf extract on juveniles exposed to ambient ammonia. Valiallahi *et al*. (2020) investigated the effects of *Lactobacillus plantarum* strain 44A in the diet of fingerlings, finding improved enzyme activities suggesting that the addition of this probiotic improved diet digestibility, including protein, starch and fattiness, and resulted in better growth performance and feed efficiency. Yousefi *et al*. (2020) recommended lavender extract (*Lavandula angustifolia*) as a dietary supplementation at levels of 1.0-1.5% to suppress stress, inflammation and oxidative conditions, and augment immune responses. There were no significant effects on growth performance. Yousefi *et al*. (2020) showed that dietary garlic at 1.0 and 1.5% promoted antioxidant, enzymatic and immune responses and was beneficial in mitigating adverse effects of ammonia toxicity. Afsar Dir *et al*. (2021) added 25 mg/kg of nano-magnesium to the fingerling diet and found improved growth, digestive enzyme secretion and innate immunity, and the adverse effects of glyphosate toxin were counteracted. Hoseini *et al*. (2021) recommended dietary supplementation with 1% Russian olive (*Elaeagnus angustifolia*) leaf extract for carp feed formulation, as it stimulated some immune and antioxidant parameters, but higher levels of olive extract should be avoided as they might cause oxidative stress and hepatotoxicity. Hoseinifar *et al*. (2021) investigated the effects of apple peel-derived pectin in the diet and found it to favourably affect growth and immune response. Mirzaee and Naderi (2021) determined the effects of replacing soybean meal by canola meal on growth and found 50% substitution was effective. Pirani *et al*. (2021) suggested that dietary supplementation with turmeric (50 g/kg) or curcumin (1,000 mg/kg) can play an important role in enhancing growth performance and fatty acid composition and administration of curcumin nanomicelles may have a potential ameliorative effect against silver nanoparticles. Sohrabi *et al*. (2021) concluded that powdered leaves of guava (*Psidium guajava*) were a beneficial additive for growth performance and immune status of fingerlings although further research was needed to determine optimum levels. Yousefi *et al*. (2021) added marjoram (*Origanum majorana*) extract to the diet and recommended 200 mg/kg as it stimulated growth, antioxidant and immune systems, which suppressed mortality during *Aeromonas hydrophila* septicaemia.

*Aquaculture:*-

Peyghan *et al*. (2002) studied the differences between gonads of fishes from two culture seasons. Yousefian (2005) generated gynogenetic carp through irradiation. Imanpour and Enayat Gholampour (2008) studied the effect of broodstock migration time on various egg characters in relation to aquaculture. Baghfalaki *et al*. (2009) showed broodstock density had an effect on survival and growth of larvae and fingerlings in earthen ponds. Imanpour *et al*. (2009) examined stocking density and its effect on survival and growth in polyculture, up to 450 fish per hectare being optimal. Imanpoor *et al*. (2009) found an increase in production output of carp in polyculture by eliminating goldfish with the introduction of the predator *Sander lucioperca* (pike-perch). Imanpour *et al*. (2009) examined the effects of broodstock age

on various egg dimensions, females aged 3-6 years being found suitable for propagation. Imanpour and Safari (2009) studied the effect of maturation stages on gonadal indices and chemical composition of the gonad. Kordjazi *et al*. (2009) measured physicochemical parameters of water and their correlation with haematocrit indicators, growth and survival in farm ponds.

Fallahi (2010) showed that using slurry in aquaculture ponds was effective in promoting the growth of zooplankton which is the food of the fish larval stage. Rafiee and Hekmat (2010) showed the usefulness of populus shavings as a biofilter medium in a recirculating culture system. Yousefian *et al*. (2010) examined the effect of zeolite on improving the environmental condition and immune potency of Mazandaran carp, finding reductions in ammonia and pH and increased oxygen in the pond, and an increased immune response. Ebrahimi (2011) reared juveniles in tanks with different background colors (white, black, red, blue and yellow) and found bright colours could improve optimum culture conditions while elevated cortisol levels in black and red tanks showed chronic stress. Ghelichi *et al*. (2011) detailed oocyte development from beach seine caught fish and determined spawning occurred in spring. Mohammad Nejad Shamoushaki *et al*. (2011) used white rearing tanks for fingerlings where better growth was exhibited than in red, blue or black tanks. Pourgholami Moghaddam and Abdollahpour Biria (2011) recorded the return rate of carp 4-7 months after release in the western Anzali Lagoon with other Chinese carps. Common carp comprised 11% of the releases and final biomass was 23.5 t (32.5% and 167.8 t for *Hypophthalmichthys molitrix* for comparison). The average size of the common carp was 8.7 cm and 1,208 g. Overall survival rate was 10%. Shamsaei Mehrjan and Amini (2011) were able to integrate production of earthworms (*Eisenia foetida*) with farming carp. Shirali *et al*. (2011) described the histological development of the ovary during the breeding season. Yousefian *et al*. (2011) recorded heritability of growth-related traits in wild common carp. Yousefian (2011c) found a positive correlation between fertilisation rate and egg size (larger eggs offer a larger target to sperm) and a negative correlation between fertilisation rate and fecundity (egg size decreases with increase in number of eggs), egg size therefore being important in aquaculture. Akbarian *et al*. (2012) found that juveniles grown in blue tanks had the best growth performance and carcass protein. Darvish Bastami *et al*. (2012) examined biochemical parameters of seminal and blood plasma and their correlation in wild fish, used to evaluate physiological condition. Kordjazi *et al*. (2012) found a salinity of 0.3-2.7 g/l and an electrical conductivity of 843-5,230 μm/sq cm without stress favoured growth. Mashinchian Naderi *et al*. (2012) treated and reused wastewater from cultivated carp aquaculture after bioremediation using several *Bacillus* species, when water conditions improved and larvae increased in weight. Peykaran (2012) used aeration and nutrition management to increase production of warmwater fish, including common carp, in West Azarbayjan ponds, attaining a 50.5% increase from the previous year. Rahnama *et al*. (2012) investigated characters of Bandar-e Torkeman fish hatchery brooders, finding male length and weight were 253-660 mm and 265-3,670 g and females were 305-602 mm and 310-2,900 g, all fish were 2-14 years, absolute fecundity was 77,447-430,745 eggs, and age groups and individual ages had decreased probably related to unsuitable reproduction and feeding conditions and overfishing. Shirali *et al*. (2012) gave histology of ovarian development in carp from culture ponds in Khuzestan. Aliniyah *et al*. (2013, 2013) studied the influence of age on broodstock reproductive traits and fertilisation, crossing fish of different ages achieving better fertilisation and survival for example (two-year-old males with three-year-old females) and higher hatching

rate and larval length during hatching for example (three-year-old males with two-year-old females). Farhoudi *et al*. (2013) recorded changes in digestive enzyme activity during larval ontogeny, useful in feed formulation. Imanpour *et al*. (2013) found that liming of fish ponds increased growth of carp. Sadeghinejad Masouleh (2013) examined culturing black carp (*Mylopharyngodon piceus*) with other Chinese carps and with common carp. By the second year, the black carp reached acceptable market size and could be compatible with common carp and grass carp in aquaculture. Sadeghinejad Masouleh *et al*. (2018) noted that black carp were introduced in 1992 from China for polyculture and could be stocked at 250 “pieces” or fish per hectare. Aghili (2014b) studied brood stock production from fingerlings in pen culture in Gorgan Bay with adaptation to brackish water over 7-10 days, details of pen sizes and feeding programmes, survival and growth, and autopsy to confirm maturity of both males and females. Imanpour *et al*. (2014) studied the effect of liming on ponds in the Dikjeh Gonbad area of Golestan and found positive effects on the physico-chemical parameters of water, improving breeding conditions for carp. Naderi Samani *et al*. (2014) used five species of probiotic bacteria to bioremediate cultivation pond effluent where fish could then be reared more successfully than in untreated water. Soleimani *et al*. (2014) used microsatellite markers to study carp on farms in Khuzestan as artificial reproduction could reduce genetic diversity. Vaisi and Pejmanmehr (2014) determined parentage assignment using the UBA gene to avoid inbreeding depression.

Ghafari and Falahatkar (2015) studied the effect of age on reproductive indices in two- and three-year-old females, finding those of higher age, weight and size were more appropriate for artificial reproduction. Hedayati and Heidari *et al*. (2015) found the number and size of chloride cells in the gill increased with increases in the environmental factors salinity and temperature. Imanpour *et al*. (2015) examined the effects on carp of morning liming of culture ponds, finding significant effects on blood haematocrit but not on blood glucose, magnesium, calcium and sodium. Mehrabi *et al*. (2015) investigated polymorphism of an insulin-like growth factor binding protein-3 (*IGFBP-3*) gene and found significant relationships between the detected genotypes and condition factor, enabling breeders to use marker assisted selection. Vazirzadeh *et al*. (2015) used measurements of plasma phosphorus levels for selecting wild-caught ripe females for artificial spawning, this measurement being highly correlated with vitellogenin levels but cheaper to assess. Adeli *et al*. (2016) suggested a feeding frequency of three times a day for best fingerling growth performance. Azari Takami and Maghsoodifar (2016) studied the complete omission of artificial feed by using the synergistic effect of warmwater fish polyculture (common carp as omnivore, silver carp as phytophage and bighead carp as zooplanktophage). The study found suitable individual growth of the fish species, higher total production, and lower total prices due to the omission of feed in the synergistic culture and this achieved more benefits than the control cultures of warmwater fish consuming artificial feeds. Hosseinzadeh Sahafi (2016) found imported $F_1$ generation Chinese carps, including common carp, from China increased overall production in aquaculture 31%. Irani *et al*. (2016a) evaluated barley straw, wood chips, sponge and PVC pure pipe based biofilters in a carp aquaculture recirculation system finding sponge-based biofilters had the best performance, PVC pure pipe the poorest and the other two were acceptable, and the highest feeding and growth performance was with the barley straw biofilter. Irani *et al*. (2016b) found that barley straw, wood chip and sponge biofilters were well activated in a carp aquaculture recirculation system. Laloei (2016) used the luciferase gene as a genetic marker for detection of carp. Parafkandeh Haghighi (2016) tagged fingerlings using tetracycline that could later be detected

by examining the otoliths. Aminian Fatideh *et al*. (2017) aimed to investigate changes in behaviour of carp in an experimental pond condition using a variable voltage electric field in different water salinity during entanglement of fishing gear. Water salinity (0-8 g/l) did not have a significant effect on the distance of carp from the electric source while an increase in voltage had significant impact on the distance of carp from the electric source. In all water salinity treatments, the maximum convulsion was recorded in voltages higher than 150 volts, and mortality was observed at higher voltages, above 225 v. Erfani Majd and Rahdar (2017) carried out histomorphometrical studies of alarm cells in different parts of female carp skin in reproductive and non-reproductive seasons, finding that the most and largest alarm cells were present in the head area in both seasons. Haghpanah and Iri (2017) studied culture of wild common carp in earthen ponds in Golestan Province finding significant growth in 6.5 months from 41.46 g to 712.49 g with survival at 81.83%, and carp was found to be suitable for polyculture in the Golestan climate. Haghparast *et al*. (2017) and Mehdi Haghparast *et al*. (2017) studied the effect of using biofloc technology on carp biochemistry and intensive culture. The technology reduces water consumption and increases the intensity of production based on heterotrophic bacteria instead of any biofilter system. The technology gave a high protein ratio and carcass protein increased significantly, and there was a significant increase of bacteria in the water and in the fish intestines. Harsij (2017) studied the use of poultry slaughterhouse wastewater in fingerling culture, finding no mortality and statistically significant differences in ammonium, nitrate, phosphate, alkalinity, total hardness and conductivity but none for dissolved oxygen, temperature, pH and total dissolved solids. Harsij and Adineh (2017) showed that poultry slaughthouse waste, mixed with fresh water, could be used in carp culture. There was no improvement in growth but caracass composition was significantly different. Hatefi *et al*. (2017) found no significant differences in growth and body shape deformities between diploid and triploid fish. Keyvanloo *et al*. (2017) investigated the toxicity of some permeable and non-permeable cryoprotectants used in embryo preservation, finding decreased hatching rate with increased concentration and duration of exposure, and the permeable cryoprotectant methanol being the least toxic. Mazahery Tehrani and Keramat Amiri (2017) described the physical characteristics of extruded and pressed pellets used in aquaculture. Peyghan *et al*. (2017) attributed pond mortalities as due to *Microcystis* and *Anabaena* algal blooms in Khuzestan Province. Talebzadeh *et al*. (2017) used 20 p.p.m. of chloramine and 4 p.p.m. of methylene blue to significantly decrease bacterial and fungal flora on koi juveniles. Aghili *et al*. (2018) compared wild and cultivated broodstock to study the effects of age and weight on such reproductive characteristics as percentage of fertilisation, number of fertilised eggs, number of early hatched larvae, egg diameter and number of eggs per gram. The only significant effect was on percentage of hatching, which was higher in wild fish and also depended on weight and age of females. Farahi *et al*. (2018) used carp to assess the giant gourami (*Osphronemus goramy*) as a new edible species, when reared in concrete pools. Although the gourami could be considered as a valuable farmed fish, as it had fillet and carcass yields and certain essential and non-essential amino acids significantly higher, the carp had better growth and better values for carcass yield and visceral index. Khatib Haghighi *et al*. (2018) examined phytoplankton in carp polyculture with northern pike, *Esox lucius*, and found the pike had no effect on the abundance and variety of the phytoplankton. Mahmoudi Khoshdarehgi *et al*. (2018) found that feeding fingerlings in a biofloc system with a diet containing 27 and 31% protein gave the best results in terms of water quality and growth. Marandi *et al*. (2018) showed tank colour and rearing density significantly affected growth and

feed performance. Mehdi Hagh Parast Radmard *et al*. (2018) showed that fish reared in a biofloc system (different C/N ratios increasing heterotrophic microorganisms) were significantly better than control although growth and health parameters were not different. Naderi Rad *et al*. (2018) found that urban wastewater without water mixing had the potential for re-use in aquaculture and the presence of fish improved water quality parameters. Raoufi *et al*. (2018) determined that cage culture in Golestan Reservoir had no significant effect on water quality and structure of the zooplankton population. Rezaie Tavabe *et al*. (2018) investigated the effects of carp and silver carp (*Hypophthalmichthys molitrix*) on qualitative indices of wastewater in the Semnan wastewater treatment plant and found a significant reduction in biological oxygen demand, chemical oxygen demand and total suspended solids. Yousefian *et al*. (2018) used zeolite to improve water conditions and, with good management, growth in Caspian Sea carp improved. Bakhshi *et al*. (2019) demonstrated that fingerlings cultured in a biofloc system had an acceptable quality flesh. Jani Khalili *et al*. (2019) found an application of 1 kg/cu m of vermicompost (worm-composted food waste) improved water quality, plankton and fry performance in fibreglass tanks, compared to various levels of compost fertiliser and cow and chicken manure. Keivanloo *et al*. (2019) showed cryopreservation of embryos was possible for up to seven days at -2ºC while survival did not occur at 14 and 21 days. A combination of methanol with propylene glycol as a cryopreservation solution had a higher survival rate after one and seven days compared to methanol with dimethyl sulphoxide and sucrose. Mohammaditabar *et al*. (2019) identified problems and limitations in development of carp farming in Rasht, Gilan. The most important economic problems were high bank charges and the high cost for ingredients for aquaculture (food, fertiliser, fingerlings, fuel, energy, water charges, etc.). The low consumption per capita of farmed fish and poor operation of warmwater farms were the most important social problems. The lack of aquaculture experts, lack of communication between research centres and fish farms, and low production per unit area were the most important policy and management issues. Insufficient training courses, unavailability of the internet and scientific journals for fish farmers, and low education levels of farmers were the most imporatnt technical problems of education and promotion. Mohammadjafari and Imanpoor (2019) examined the use of alkalase, tannic acid and sodium chloride for removing egg adhesion instead of carbamide solution and found the best fertilisation rate (99.57%) and hatching rate (99.46%) was at 500 mg/l tannic acid for 30 seconds.

Abbasimesrdashti *et al*. (2020) showed satiation feeding at high and low density had a positive effect on growth performance and haematological parameters of juvenile koi. Aghili *et al*. (2020) described benthic communities under pen-cultured carp in Gorgan Bay. Ebrahimi *et al*. (2020) found a normal range of crud protein (35-40% sugarcane molasses and rice bran) suggested that microbial flocs could not compensate a 15% reduction of crud protein in juvenile diets but using molasses and rice as carbon sources improved growth performance, immune and antioxidant status in the fish when fed 30% crud protein. Haghparast *et al*. (2020) studied the effect of cane molasses as a carbon source in a biofloc system on haemato-immunological parameters, antioxidant status and stress indicators. Results showed that most of the immunological parameters as well as resistance against bacterial infection increased in biofloc groups, haematological parameters and antioxidative enzyme activity were not affected, and stress indicators showed a significant decrease in the biofloc system, particularly in carbon/nitrogen ratio of 20. Hatefi *et al*. (2020) found that heat shock at 40ºC, six minutes after fertilisation, for two minutes was the most effective treatment for induction of triploidy in

koi. Hermand *et al*. (2020) studied the effect of feeding frequency on the performance of growth, nutrition, survival and carcass composition of young koi and found that by increasing feeding up to five times a day, all parameters were improved. Jahanatighi *et al*. (2020) studied the effect of two species, *Phragmites australis* and *Cyperus rotundus*, and their phytoremediation effects on carp breeding tank water effluent, and found the plants have a high potential to absorb nitrates, nitrite, ammonium, and phosphates. Minabi *et al*. (2020) evaluated growth and production in an aquaponic system or fish-plant co-culture at Ahvaz, Khuzestan involving basil (*Ocimum basilicum*) and found it to be much more efficient and more effective in saving fresh water consumption but the cost was higher than a traditional system. Minabi *et al*. (2020) found, overall, a biofloc system with carbon/nitrogen at 19:1 improved the water quality and growth performance of fingerlings while not negatively affecting the carcass proximate analysis. Sugarcane molasses was used as the carbon source. Yousefi Siahkalroodi *et al*. (2020) determined the proximate composition (protein, lipid and ash) and moisture percentage, as well as amino acid profiles, of Asian sea bass (*Lates calcarifer*) cultured in cage condition, rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) and found Asian sea bass and rainbow trout had a higher nutritional value for consumers than common carp and Nile tilapia. Abolghasemi and Taati (2021) showed that the use of cultured chironomid larvae (*Chironomus albidus*) at 60 g/sq m in the wastewater of fingerling rearing tanks had a positive bioremediation effect in reducing harmful water compounds such as total suspended solids, orthophosphate, ammonia and nitrite. Marzban *et al*. (2021) conducted a study on 115 randomly-selected carp fish farms to investigate and predict the yield and environmental emissions final score in Shushtar County, Khuzestan. The total input energy, the yield and energy ratio were 293,127.95 MJ/ha, 3,389.28 kg/ha, and 0.30, respectively. Electricity and feed consumption had the highest contributions to total input energy and environmental emissions. The normalisation results showed that the marine aquatic ecotoxicity and freshwater aquatic ecotoxicity had the highest values among all impact categories with $671.50 \times 10^{-9}$ and $152.60 \times 10^{-9}$, respectively.

*Chemical composition and food safety:-*

The carp is characterised as a fatty fish according to a lipid content 9-14% by wet weight of muscle in autumn in Iraq (Hantoush *et al*., 1999). Al-Aswad *et a*l. (1980) detailed the chemical composition of this species in Dukan Lake, Iraq including seasonal levels of moisture, fat, protein and ash, and the various types of fatty acids and amino acids. Hindi *et al*. (1996a) gave the chemical composition of flesh of this species in Iraq as 78.87% moisture, 2.46% fat, 17.06% protein and 1.35% ash, indicating a valuable food fish characterised as lean to medium fatty. Hindi *et al*. (1996b) gave chemical indices for assessing fish freshness in Iraq according to the month of capture and marketing (pH 6.28, total volatile nitrogen bases 11.07 mg/N/100g fish, thiobarbituric acid 0.47 mg, and free fatty acids 0.62%).

Moini and Basimy (2004) reported on production of fish cake in Iran according to various recipes and its shelf life. Khoramgah *et al*. (2007) examined wild and farmed carp for proximate and fatty acid composition finding no significant differences. Safari *et al*. (2008) studied changes in muscle chemistry during maturation. Nemati *et al*. (2009) determined that eight days is the maximum shelf life of fish burgers stored in a refrigerator based on proximate, chemical and sensory evaluations. Ojagh *et al*. (2009) compared the nutritional composition and fatty acids in muscle tissue of the common carp and compared it with the grass carp, finding no differences in protein, lipid and ash, while grass carp had higher moisture content, and most fatty acids showed significant differences. Yehganeh *et al*. (2009) recorded seasonal

variation in the chemical composition and fatty acid profile of ovaries, necessary for embryogenesis.

Khodanazary and Shabanpur (2010) compared filleted and gutted carp salted at 4ºC for 10 days, finding differences such as higher protein and moisture in gutted samples, among others. Shaabanpour *et al*. (2010) examined the changes in chemical content and yield of carp under different salting methods, finding, for example, that lower salt concentrations gave higher weight, protein and moisture and lower fat and salt. Yeganeh *et al*. (2010) found pre-spawned carp showed a higher variation in lipid quality as frozen fillets. Zolfaghari *et al*. (2010) determined that fish size had a positive relationship with lipid content and fillet dry weight yield. Afkhami *et al*. (2011, 2011) compared chemical composition with *Ctenopharyngodon idella*, there being significant differences in protein, lipid and moisture but not in ash. Farhoudi *et al*. (2011, 2011, 2011) studied changes in the body composition, lipid and fatty acid profile of larvae during development in order to determine nutritional requirements and improve product quality. Rahimabadi *et al*. (2011) described the effects of frying in sunflower oil on proximate and fatty acid characteristics of fish fingers made from mince and surimi. Saberi *et al*. (2011) determined the amounts of omega-3 and omega-6 fatty acids in this species. Sary *et al*. (2011) compared the chemical composition of muscle in carp and Indian white shrimp (*Fenneropenaeus indicus*) finding such differences as higher protein in shrimp and higher energy level in carp. Shabanpour and Ebrahimi (2011) compared the chemical composition and sensory evaluation parameters of carp with giant gourami (*Osphronemus goramy*) and *Oncorhynchus mykiss* (rainbow trout) finding the Entire Colour Index was highest in carp although colour, flavour and total acceptance of the gourami fillet had the highest scores. Dorafshan *et al*. (2012) measured carcass quality of cultivated fish with values for two-year-old fish of protein 50.16%, ash 18.03% and total lipid 20.44% dry weight. Ghomi *et al*. (2012) studied the proximate composition and fatty and amino acids in this fish determining that though it has a lower commercial price and delicacy, it does not have a lower nutritional value than *Rutilus kutum*. Hasani *et al*. (2012) investigated the quality of fish fingers produced from common carp fillets and surimi and stored in a refrigerator, determining a shelf life of six days. Velayatzadeh *et al*. (2012) examined levels of drip, drip protein and total volatile base nitrogen (TVB-N) as measures of spoilage of fish kept refrigerated at -18°C with various salt levels, the highest TVB-N being in 2% salt in this species of four species examined. Yeganeh *et al*. (2012) assessed seasonal variations in the chemical composition and fatty acid profile of fillets, polyunsaturated fatty acids increasing in cold seasons for example. Yeganeh *et al*. (2012) compared the seasonal variations in chemical composition and fatty acid profile of farmed and wild carp, finding wild carp provided the consumer with much higher levels of arachidonic acid, docosahexaenoic acid, eicosapentaenoic acid and ω3 polyunsaturated fatty acid and n-3/n-6 ratio, and the fatty acid profile was higher in winter. Assareh *et al*. (2013) studied the effect of starvation, which could occur before and during capture and while migrating, on carcass quality. Jafarpour *et al*. (2013) assessed microbial and biochemical characteristics of sausage made from minced fish and fermented by the bacterium *Pediococcus pentosaceus*. Jarfarpour *et al*. (2013) added soy protein isolate to surimi at 10% and found enhanced gel strength but other parameters were not enhanced and it was not recommended. Ojagh and Shabanpour (2013) were able to differentiate this cultured carp from others by the composition of fatty acids, which are probably determined by food sources and enzymatic activity of fatty acid biosynthesis. ChelemalDezfoul Nejad *et al*. (2014) measured the chemical composition of fillets of carp fed haematococcus (*Haematococcus pluvialis*)

microalgae powder where 2g/kg in the diet had a positive effect. Farjami and Hosseinie (2014) studied the effect of Persian thyme extract (*Zataria multiflora*) on the microbial and chemical quality of surimi refrigerated at 1 ± 4ºC, finding the extract had anti-bacterial properties for a short period. Ghelich and Sheykhi (2014) compared the chemical composition of Caspian Sea wild, farmed wild and farmed carp finding the former more nutritious, although all were valuable foods. Hasani and Hasani (2014) studied the antimicrobial properties of red grape extract on fillets stored at 4ºC, shelf life being best overall with a 4% extract. Hosseini (2014) found that the biogenic amines such as putrescine and cadaverine (formed by bacterial conversion of disintegrated proteins even under refrigeration) are good markers to determine quality of carp flesh. Jafarpour *et al*. (2014) gave details of the preparation of protein powder from carp mince and surimi and its formulation into a cookie. Sahari *et al*. (2014) examined vitamin loss during storage of frozen fish, some vitamins showing significant loss and others not - the carp had the highest niacin content of five species studied, for example. Tarkhasi *et al*. (2014) assessed three type of fish fingers (chopped fillet, minced and surimi) with the latter having the highest quality. Zamaninejad *et al*. (2014) found that a two-step process of heating surimi gel and increasing setting time to eight hours in a medium temperature improved gelling and increased texture quality. Ziaei-nejad *et al*. (2014) demonstrated a lack of effect of mycotoxins and prymalak (= primalac) probiotics on protein, fat and ash in the fish carcass.

Anousheh *et al*. (2015) studied the effect of delayed icing (three and six hours delay) on the quality of surimi and found an increasing loss over time. Farjami and Vali Hosseini (2015b) used 4% thyme extract to enhance shelf life of raw, refrigerated surimi. Ghelichi *et al*. (2015) compared the nutritional value and fatty acids profile of wild carp in natural and cultivated environments. Both were considered an invaluable nutritional resource but wild carp were more nutritious than farmed carp thanks to higher rates of various fatty acids. Jafarpour (2015) compared mince and surimi prepared from carp during three months of frozen storage finding properties of surimi remained nearly constant while mince declined significantly. Jafarpour *et al*. (2015) evaluated the chemical, biophysical and sensory characteristics of beef burgers containing carp surimi. Javadian *et al*. (2015) found that a sodium alginate coating, enriched with *Enteromorpha* sp. algae extract, effectively reduced the decay rate of toxic chemicals and improved the sensory status of fillets in cold storage. Jorjani *et al*. (2015) determined the shelf life of carp fish burgers during frozen storage was best at five months at -18°C. Morshedi *et al*. (2015) examined fish from Behshahr on the Caspian Sea and the Anzali Wetland and found moisture, ash, lipid and protein in the sexual rest stage were higher than in the ripeness stage. Nazarpour *et al*. (2015) assessed the fatty acid composition of raw muscle and barbecued fillets of carp. Results showed that the level of saturated fatty acids and polyunsaturated fatty acids in raw muscle was higher than their level in barbecue fillet, but monounsaturated fatty acids were higher in barbecue fillet. Oleic acid was the dominant fatty acid in raw muscle (41.43%) and barbecue fillet (48.01%) of farmed carp, while gadoleic acid was not detected. There were no significant differences between eicosapentaenoic acid, n-3 and n-3/n-6 levels in raw muscle and barbecue fillet, but docosahexaenoic acid and n-6 had significant differences. N-3 and n-6 fatty acids in raw muscle were higher than barbecue fillet, while eicosapentaenoic acid and docosahexaenoic acid in barbecue fillet was higher than raw muscle. Hasani and Javadian (2016) found that bitter orange peel and beta-hydroxytoluene reduced chemical deterioration and lipid oxidation of fillets during 16 days of refrigerated storage. Hedayatifard *et al*. (2016) studied the effect of cold-smoking for 30 days at 4ºC on the production of polycyclic aromatic hydrocarbons (PAHs), quality indices, the microbial

community and omega-3 fatty acid profile. The smoked fish had PAHs but below the maximum allowed, protein and lipid content increased and moisture decreased, the microbial community was well-controlled, and the fatty acid profile did not change and useful compounds were conserved. Khatami *et al*. (2016) examined the effect of dietary *Spirulina*, a cyanobacterium, on lipid and protein oxidation as measured by muscle malondialdehyde concentrations, finding less oxidation. Koliaee *et al*. (2016) found that the probiotic bacterium *Bacillus subtilis* in the diet could affect the fatty acid composition of fillets. Mohebbi Moghaddam *et al*. (2016) found dietary β-carotene was a natural antioxidant largely effective in improving stored carp flesh by reducing lipid and protein oxidation. Shabanpour *et al*. (2016) showed that the best surimi quality and lowest protein degradation were found in samples produced with an alkaline-acid process and Shabanpour and Etemadian (2016b) found that carp surimi produced with acid and alkaline solubilisation has a significantly higher yield than conventional surimi. Ali Noori *et al*. (2017) used a 1.5% lactic acid solution as a safe preservative for carp fillets at 4°C. Askary Sary *et al*. (2017) studied the effects of different cooking methods on concentrations of the essential elements copper, iron, nickel and zinc and found variations with fried, grilled, microwaved and steamed fish although none were above acceptable limits. Jafarpour *et al*. (2017) found that fish made into fermented sausage and inoculated with mixed starter cultures of lactic acid bacteria (*Pediococcus pentosaceus* and *Lactobacillus plantarum*) had more favourable physicochemical characteristics and textural properties as compared to a control group. Jafarpour *et al*. (2017) investigated oil extracted from carp by-products using various methods, finding the wet rendering method had the best quality but lowest yield, the Soxtec apparatus had the highest efficiency, and ultrasound had the highest yield but lowest quality. Reyhani Poul and Jafarpour (2017) determined the effects of hydrolysis on the functional properties and antioxidant activity of hydrolysate from carp head and frame by-product. Hydrolysate is also used as animal food and fertiliser. Bakhshi *et al*. (2018) recorded that flesh from carp reared in the biofloc system and stored at 4ºC had increased quality and shelf life. Choobkar *et al*. (2018) found that skin gelatin from carp could be used to replace commercial gelatin from pigs and cows which are unacceptable for religious reasons and the risk of transmission of bovine spongiform encephalopathy. Colour parameters and mineral content were good. Mirzapour Kouhdasht *et al*. (2018) also produced gelatin from carp wastes by enzymatic hydrolysis. Farahi *et al*. (2019) compared fillet quality with the giant gourami (*Osphronemus gouramy*) and found total omega-6 fatty acids were higher in carp while docosahexaenoic and eicosapentaenoic acids were higher in the gourami and the ratio of polyunsaturated fatty acids to saturated ones was more favourable in carp. Kazemi Karaji *et al*. (2019) developed a non-destructive machine vision system based on gill and eye color and on textural features to assess fish quality and freshness. Sheykhi *et al*. (2019) combined carp meat with beef meat in the production of non-fermented sausages, finding 35-65% fish meat was best in regards to physiochemical and textural properties. Taheri-Garavand *et al*. (2019) proposed an image processing method in combination with an intelligent adaptive neuro-fuzzy inference system for classifying common carp bodies based on the freshness factor during the storage period under ice-covered conditions, a low-cost, simple and non-destructive method.

Ahmadi *et al*. (2020) produced a protein hydrolysate antioxidant compound from fish by-product, carp viscera, in order to prevent the disposal of this by-product in the environment and to provide a product that can be used in the food industry. Bahrani *et al*. (2020) investigated the essential amino acid content (for humans) in carp muscle and found all of them to be present, and recommended carp for the human diet. Ehsani *et al*. (2020) indicated that a

chitosan film containing a lactoperoxidase system extended the shelf life of fish burgers in comparison with other treatments and a control for five days. Kheiri *et al*. (2020) found natural antioxidants in Aras River carp flesh had beneficial effects for human consumption, although perch (*Perca fluviatilis*) flesh had higher antioxidant properties and regenerative capacity. Tabatabai Niko *et al*. (2020) studied the effect of adding *Gracilaria persica* macroalga powder in place of nitrites on some physicochemical properties of common carp sausage during refrigerated storage and found a level of 9% showed the best results. Taghavi *et al*. (2020) indicated that aqueous and ethanol extracts of pomegranate peel (*Punica granatum*) added at high concentrations to minced carp played an important role in ensuring food safety as shown by the antibacterial effect on inoculated *Escherichia coli* as well as antioxidant and preservative properties. Taheri-Garavand *et al*. (2020) used fish imagery to monitor and classify fish freshness. Yeganeh *et al*. (2021) found different concentrations of carp head protein hydrolysate scavenged and reducted ferric ion, so this hydrolysate can be considered as a dietary supplement with a desirable antioxidant function.

*Disinfection and healing:-*

Soltani *et al*. (2001) studied the antifungal effectiveness of formalin on hatch rate of eggs. Vahabzade Rodesari (2003) found that 750 p.p.m. of hydrogen peroxide used with common carp eggs controls moulds and increases hatching rate significantly compared to malachite green. Vahabzadeh Roodsari *et al*. (2003) compared malachite green and hydrogen peroxide to control fungal infections (the latter was effective and less dangerous). Sharifpour (2004) studied the histology of the response and the circumstances of wound healing. Kazemipour *et al*. (2005) used garlic, mallow and motherwort in healing superficial wounds - garlic at 0.1 g/l reduced recovery by one week. Khodabandeh and Abtahi (2006) used sodium chloride, iodine and formalin to control *Saprolegnia* sp. on eggs (sodium chloride was recommended). Hasanabadizadeh *et al.* (2008) documented the lack of improvement in wound healing after vitamin injections. Soleymani *et al*. (2008) showed the effectiveness of vitamin C injections on survival of juveniles challenged by different doses of the theront (infectious stage) of *Ichthyophthirius multifilis*.

Balouch *et al*. (2010) found that long-term baths in zinc sulphate had positive effects on skin wound healing. Nematollahi *et al*. (2010) described the inheritance of congenital interrenal hyperplasia. Papi *et al*. (2010) found that salt baths of 2 or 3% concentration improved wound healing. Basir *et al*. (2011) found that injection of killed bacteria (*Aeromonas hydrophila,* a causative agent for septicaemia in fishes) elevated the serum antibody level. Imanpoor *et al*. (2011) showed a positive effect of sublethal concentrations of chloramin T, used to combat pathogens in densely farmed fish, on growth, survival, haematocrit and some blood parameters. Makvandi *et al*. (2012) found the optimum concentration of a salt bath for fingerling disinfection was 18‰ for an hour. Mohammad Nejad Nourzad *et al*. (2013) used mucous cells in the epidermis as an indicator of fish death time in relation to temperature and antioxidants. Bahmani *et al*. (2014) demonstrated that methanol extracts of wild marjoram or oregano (*Origanum vulgare*) had a positive effect on survival of fish infected with *Aeromonas hydrophila* bacteria. Mohammadi *et al*. (2014) showed that concentrations of 100 and 150 mg/l of *Eucalyptus globulus* (Tasmanian blue gum) extract inhibited fungal and bacterial pathogens on the skin and gills of fingerlings. Valipour *et al*. (2014) determined that a 0.5% concentration of propolis (a resinous compound collected by bees from plants, also called bee glue, a sterilant and protective barrier in beehives) in the fingerling diet stimulated humoral immunity and increased resistance to bacteria.

Mazandarani *et al*. (2015) measured copper sulphate levels for fingerlings that should not exceed 2 mg/l when used on fish farms as a disinfectant and algicide. Abedi *et al*. (2016) studied the effects of different dissolved oxygen levels on spleen histopathology in juveniles, showing congestion, cell swelling, pyknotic nuclei and loss of cytoplasm under hypoxia, cell swelling and vacuolation of cytoplasm in hyperoxia, and weight differences. Baraki Tabar *et al*. (2016) found that the drugs metronidazole and levamisole (used to treat anaerobic bacteria, protozoans and parasitic worms) had no significant effect on serum enzymes although the former in a bath treatment significantly increased cholesterol. Hosseinzadeh and Tukmechi (2016) isolated six strains of *Aeromonas hydrophila*, which cause bacterial fish disease and thus major economic losses in aquaculture, from 10 fish farms in West Azarbayjan. The bacterium could produce enterotoxin and had antibiotic resistant genes. Jangaran Nejad *et al*. (2016) investigated the use of florfenicol used in aquaculture to treat bacterial infections and found a decrease in haematological parameters and an increase in activity of serum enzymes. Ahmadian *et al*. (2017) found a 20 mg propolis ethanolic extract best healed wounds in koi carp. Moori Bakhtiari *et al*. (2017) isolated the opportunistic bacterial pathogen *Aeromonas hydrophila* from the intestines of carp taken from a Khuzestan fish farm, finding 20 strains most of which had multiple resistances to antibiotics. Moori Bakhtiari *et al*. (2017a) determined the antimicrobial resistance profile of *Aeromonas hydrophila*, finding resistance to clindamycin (90%), amoxicillin (37.5%) and streptomycin (10%), among others. Moori Bakhtiari *et al*. (2017b) evaluated biofilm formation ability in different isolates of *Aeromonas hydrophila*. Biofilm formation could lead to antibiotic resistance and the host's inherent defense. Most isolates (68.5%) had the ability to produce biofilms at a moderate level. Pazira (2017) showed that thyme essence (*Thymus vulgaris*) could be used as a substitute for commercial fungicides in aquaculture of koi carp. Peyghan *et al*. (2017) found the average amount of cholesterol in metronidazole and levamisole baths was significantly higher than in the control group. Soltanian *et al*. (2017) studied the use of the anthelminthic praziquantel in a treatment bath for fish parasites, finding fingerlings showed immunostimulant effects. Aramoon *et al*. (2018) evaluated an *Aeromonas hydrophila* biofilm vaccine and found injection efficacious while an oral vaccine was significantly influenced by the biofilm. Hedayati *et al*. (2018) showed the use of povidone-iodine (betadine) as a disinfectant led to increased gill and liver lesions. Molayemraftar *et al*. (2018) studied the interactive effects of treatment with copper sulphate and formalin baths when nitrite and ammonia are present in the water, finding mortality or a significant increase of some enzymes. Motafeghi *et al*. (2018) examined the existence in the fish flesh of malachite green, a fungal and parasite disinfectant for fish but toxic to humans, recording levels up to 0.484 mg/kg, and differences between some fish of different sizes and between some localities. Nemati *et al*. (2019) investigated the use of zinc oxide nanoparticles for removing *Aeromonas hydrophila* from water used to culture carp juveniles, finding some microbial properties, especially *in vitro*, but their ability to completely remove microorganisms was not as high as silver nanoparticles, and so zeolite coated with silver nanoparticles had a higher potential for disinfection in aquaculture.

*Hormones and immunology:-*

Dorafshan *et al*. (2003) studied induction of spawning using pituitary extract and a GnRH (gonadotropin releasing hormone stimulating follicle release) analogue in combination with domperidone (which causes prolactin release, promoting sexual maturation). Akhlaghi *et al*. (2004) described phagocytosis in relation to immunostimulants. Erfani Majd *et al*. (2009) evaluated the response of incubated ovarian follicles to common carp pituitary extract and

cultivated pituitary cells secretion. Salamat *et al*. (2009) examined pituitary primary cell culture and its secretion effect on endocrine activity of incubated ovarian follicles. Sheykhzadeh *et al*. (2009) measured the effects of *Eucalyptus* essential oil on immunological variables.

Earfani Majd *et al*. (2010) recorded the useful effect of collected pituitary secretions from cell culture on ovarian follicles in spawning induction rather than the usual common carp pituitary extract which is expensive and open to pathogen transmission. Salamat *et al*. (2010) examined ovarian follicular cells and their endocrine activity in cell culture. Soltani *et al*. (2010) studied the immune responses to *Zataria multiflora* (Persian thyme) essential oil used as an antifungal for carp eggs. Alishahi *et al*. (2011) demonstrated dietary *Silybum marianum* (milk thistle) extract could be recommended as an herbal immunostimulant. Iranshahi *et al*. (2011) detailed the immuno-stimulatory effects of prebiotic bacteria and vitamin C on fingerlings. Jolodar *et al*. (2011) identified a cDNA sequence coding for Kruppel-like factor 2B, implicated in cell growth and differentiation, from the skin mucosa. Salati *et al*. (2011) examined immunolocalisation of $Na^+$-$K^+$ ATPase in mitochondria rich cells in gills in response to different salinity levels in this stenohaline (*sic*) fish. Vazirzadeh *et al*. (2011) studied the effects of GnRH (gonadotropin releasing hormone) agonists on reproductive performance of wild females from the Caspian Sea. GnRHa increased ovulation success but mGnRHa in a cholesterol pellet had variable effects with increasing fecundity but not higher ovulation success, compared to common carp pituitary extract. Alishahi *et al*. (2012) used *Viscum album* (mistletoe) and *Nigella sativa* (fennel flower) to enhance immune response, the former reducing mortality after challenge with bacteria. Alishahi *et al*. (2012) showed that dietary herbal extracts of *Echinacea purpurea* (purple coneflower) and *Boswellia thurifera* (Indian frankincense), but not *Zataria multiflora* (Persian thyme), have immunostimulatory and growth stimulation effects comparable to two well-documented immunostimulants, ergosan and levamisole. Salamat *et al*. (2012) used synthetic common carp GnRH and carp pituitary homogenate for *in vivo* induction of ovulation and spawning. Sanchooli *et al*. (2012) studied the role of epidermal mucus and its components in the immune system. Mehdinejad *et al*. (2013) found correlations at different seasons between certain steroid hormones and biological parameters e.g., 17-beta estradiol, progesterone and testosterone with fecundities and gonadosomatic index in spring, and positive correlations of these hormones with total weight and length in autumn in migratory Caspian Sea carp. Taghizadeh *et al*. (2013) detailed changes in serum steroid hormones in migratory females from the southeast Caspian Sea, levels being closely correlated to ovarian development. Hosseini *et al*. (2014) compared immunological parameters between fish from polluted (Ahvaz) and non-polluted water (Shushtar) in Khuzestan, finding differences in lysozyme, total protein and albumin attributed to the variation in habitat conditions. Vazirzadeh *et al*. (2014) studied reproductive strategy and changes in steroid hormones in female wild and threatened carp from the southeastern Caspian Sea. Peak spawning was in late winter and early spring and most fish showed asynchronous oocyte development. 17-estradiol decreased gradually and reached a minimum value at the spawning season and a highest value at the tertiary vitellogenesis stage while 17-, 20-dihydroxyprogesterone levels were significantly higher in late winter and early spring with a maximum level associated with the oocyte maturation stage.

Abdy *et al*. (2015) found that *Aloe vera* gel had a more stimulatory effect on immune-related gene expression than Freund’s adjuvant (an antigen solution used as an immune booster). Abdy *et al*. (2016) showed that *Aloe vera* gel compared with Freund’s adjuvant had a

more stimulatory effect on the expression of immune-related genes in vaccinated carp and could be used as a novel adjuvant in aquaculture. Hoseinifar *et al*. (2016) determined that Persian hogweed (*Heracleum persicum*) was a candidate dietary phytoimmunostimulant in carp, impacting mainly the skin mucosal defenses. Khodadadian *et al*. (2016) found that fish fed white bottom mushroom powder (*Agaricus bisporus*) improved cutaneous mucosal and serum immune parameters and up-regulated intestinal cytokines gene expression, and was a promising immunostimulant in the fingerling stage of common carp culture. Mohamadi Champiri *et al*. (2016) studied the effects of different levels of vitamin C which affected levels of thyroid hormones in fry. Ansarifard *et al*. (2017) showed that inclusion of 10% dietary supplement spirulina (*Arthrospira platensis*) had a positive effect on stimulation of the immune system in koi carp. Azadi and Safari (2017a, 2017b) found that dietary ferula (*Ferula assafoetida*) powder and sodium propionate both increase the amount of proteins present in mucus. Hoseinifar *et al*. (2017) found beneficial effects of dietary medlar (*Mespilus germanica*) leaf extract on the mucosal immune system and growth performance in fingerlings. Safari *et al*. (2017a) studied the beneficial effects of including 1 and 2% sodium propionate in the diet with respect to mucosal and non-specific immune responses and growth-related gene expression. Safari *et al*. (2017b) showed that that co-administration of apple cider vinegar boosted immunomodulatory and health promoting effects of *Lactobacillus casei* and could be considered as a promising immunostimulant in the early stage of common carp culture. Soltanian *et al*. (2017) found that an injected soluble fraction of *Heracleum persicum* (Persian hogweed) enhances immune response and affords disease resistance against the bacterium *Aeromonas hydrophila* in aquaculture. Alishahi *et al*. (2018) used chitosan (derived from shrimp chitin) nanoparticles as an adjuvant (immune response booster) in fish vaccine against the bacterium *Aeromonas hydrophila*. Berenjkar *et al*. (2018) found an association between growth hormone polymorphism and body weight, but not total length or condition factor, in wild common carp. Karimi Alishahi *et al*. (2018) showed that 0.5% propolis-ethanolic extract (bee glue) in the diet was a good candidate as an immunostimulant against bacterial infection in juveniles. Alishahi *et al*. (2019) compared the adjuvant effect of propolis with that of Freund's adjuvant on the efficacy of *Aeromonas hydrophila* vaccine in juvenile carp, finding that it could promote some immune responses but more work was needed to develop propolis as a natural adjuvant. Faramazpour Darzini *et al*. (2018) showed that *Carum copticum* (ajwain) seed essential oil had antibacterial and antioxidant properties inhibiting the growth of *Escherichia coli* when injected into minced carp at 4 µl/g. Yeganeh *et al*. (2019) investigated variation in ionic and hormone indices in wild and wild cultivated carp from Bandar-e Torkeman with levels generally higher in wild fish.

Bagheri *et al*. (2020) noted that hormone injections were used on both wild and farmed carp at the Shahid Rajaei Hatchery to induce sexual maturation in artificial reproduction. They found the single-stage injection of ovaprim was more suitable for both farmed and wild carp. Although extracted egg weight and working fecundity were lower in wild than farmed broodstocks due to lower weight, hatching percentage in wild broodstocks was higher than farmed broodstocks with a coefficient of 2.18. Hosseini *et al*. (2020) showed that pectin derived from orange peel as a dietary inclusion beneficially affected growth and the immune response. Karimi *et al*. (2020) found 1-2 g/kg of dietary raffinose could promote immune competence and health indices in carp aquaculture. *Spermatology:-*

Baradaran Noveiri *et al*. (2002) studied the effects of cryopreservation on motility of spermatozoa and Baradaran Noveiri *et al*. (2006) the cryopreservation of spermatozoa using

different extenders. Ahmadi *et al*. (2008) found that the use of sperm activators increased motility and the correlation between body weight and total duration of sperm motility was significant. Darvish Bastami and Imanpour (2009) showed sperm motility was influenced by high concentration of ions.

Seifi *et al*. (2010) demonstrated the different effects of ovaprim (a commercial spawning inducing agent), human chorionic gonadotropin hormone (hCG) and pituitary extract on biochemical parameters of seminal plasma. Seifi *et al*. (2011) used ovaprim and pituitary extract to increase sperm quality over the use of hCG hormone. Chitsaz *et al*. (2012) evaluated sperm quality by examining seminal plasma parameters, in order to improve the efficiency of artificial propagation. Khara *et al*. (2012) reported the effect of several ions on sperm activity and artificial propagation performance, finding that the sodium ion had a positive effect on sperm mobility and success rate of fertilisation while calcium, magnesium and potassium had various negative effects. Seifi *et al*. (2012) found that various semen ion ratios affected sperm quality, increasing (increased $Na^+/K^+$), decreasing (increasing $Na^+/Ca^{2+}$, $K^+/Mg^{2+}$ and $K^+/Ca^{2+}$) or having no influence ($Ca^{2+}/Mg^{2+}$ and $Na^+$ and $Mg^{2+}$). Khara *et al*. (2014) tested activation solutions on motility and fertilising ability of spermatozoa finding those with NaCl increased duration of sperm motility and solutions with $Na^+$, $K^+$ and $Ca^{2+}$ ions all increased fertilisation and hatching rates.

Seifi *et al*. (2015) examined semen spermatological and biochemical parameters finding that sperm quality of cultured carp was better than in wild common carp. Vazirzadeh *et al*. (2016) compared several hormone treatments in an attempt to improve induction of spermiation in wild-caught carp from the Caspian Sea basin, GnRHa-FIA (salmon gonadotropin in Freund's incomplete adjuvant) being the most effective. Mohammadi *et al*. (2017) found that appropriate adjustments of dietary protein, minerals and cholesterol in the spawning season increased the quality of sperm.

*Haematology:-*

Ghanbari *et al*. (2009) analysed the long-term effects of changes in pH on haematological parameters in fingerlings.

Alimohammadi *et al*. (2010) studied temperature effects on blood parameters, red blood cells for example increasing at 32ºC and decreasing at 15ºC, with other changes also, depending on time of exposure. Kordjazi and Imanpoor (2010) measured pH and ions in the water and their effects on blood serum in pond fish. Mohammadnejad Shamoushaki *et al*. (2011) found no effect on blood serum parameters with a range of feeding frequency (3-6 times per day) of fingerlings. Salati *et al*. (2010) studied changes in blood parameters used to monitor salinity effects. Sheikhzadeh *et al*. (2011) studied the effects of essential oils from *Zataria multiflora* (Persian thyme) and *Eucalyptus globulus* (Tasmanian blue gum) on haematological parameters and respiratory burst activity in relation to health during temperature stress. Amini *et al*. (2013) found a significant relationship between organic and ionic water parameters and haematological indices. Gholami *et al*. (2013) carried out a survey of sodium and potassium levels in blood serum of fingerlings at different levels of salinity (0-20 p.p.t.), where all fingerlings died at 15 and 20 p.p.t. after 24 hours, potassium decreased with time and increased salinity, and sodium increased to three days but decreased on the fourth day. Hoseini and Ghelichpour (2013a) examined the effects of fasting for various periods on serum characteristics finding significant differences in serum glucose, lactate, triglyceride and total protein but not cholesterol, albumin and calcium. Mohammad Nejad Asareh *et al*. (2013) found that starvation, which might occur during capture and transportation, had marked effects on

blood parameters and survival dropped noticeably. Baghizadeh *et al*. (2014) studied the effects of age on blood and biochemical parameters, useful in management and culture of the species. Mohammad Nejad Shamoushaki *et al*. (2014) demonstrated differences in blood serum biochemistry parameters compared to *Ctenopharyngodon idella* and *Hypophthalmichthys molitrix*. Mohammad Nejad Shamoushaki and Hojjati (2014) recorded haematological and blood serum factors in young fish. Vatankhah *et al*. (2014) investigated the effect of adding cow bile salts to the diet of fry and found varying results (no effect on growth, survival, protein, ash and carcass moisture, while total amount of protein, white and red blood cells, haemoglobin, haematocrit and others were significantly different).

Akrami *et al*. (2015) found that dietary supplementation with garlic oil at 250 mg/kg improved haematological, biochemical and immunity parameters in juveniles. Baghizadeh and Khara (2015) demonstrated variability in haematology and plasma indices associated with age, sex and hormonal treatment, useful for monitoring health of the fish. Beikzadeh *et al*. (2015) found that oral administration of cortisol could increase blood glucose as an energy source in fingerlings. Ghafari Farsani *et al*. (2015) described the adverse effects of the seed fungicide carboxin-thiram on gill structures and blood parameters. Loukhi *et al*. (2015) gave nucleotides to juveniles and found haematological and serum biochemical parameters including glucose, total protein, cortisol, C3 and C4 proteins showed significant differences at 1% of the diet. Banaee *et al*. (2016) found that administration of yarrow extract (*Achillea millefolium*) at 104 and 208 mg/kg in basal feed significantly modulated blood biochemical parameters of carp infected with lower concentrations of the bacterium *Aeromonas hydrophila*. Karami *et al*. (2016) showed that an aqueous extract of the seaweed *Sargassum angustifolium* could be effective in improving haematological parameters. Mohammadi-Sarpiri *et al*. (2016) found haematological changes following manipulation of copper and zinc in juvenile diets and the need for careful use of these essential trace elements as supplements. Shafiei (2016) determined that an alcoholic extract of pomegranate peel gave an overall improvement in haematological parameters, lysozyme activity and total protein when 300 mg were added to the diet of fingerlings. Sharifzadeh *et al*. (2016) found the optimal proportion of vitamin $B_2$ in dietary fish meal for fingerlings was 20 mg/kg in terms of positive growth and blood factors. Soleimany *et al*. (2016) investigated the pre-clinical safety and toxicology of marshmallow extract (*Althaea officinalis*) as a naturopathic medicine and found 10 g amounts led to cytotoxicity and modifications in blood biochemical parameters while at lower levels the extract had moderate antioxidant properties, leading to the recommendation of using lower concentrations in clinical studies. Ahmadnezhad *et al*. (2017) found some haematological changes in male koi exposed to the electromagnetic waves of a mobile phone (900 MHz). Akrami and Shamloofar (2017) found that dietary onion powder at 0.5% of the basal diet improved biochemical parameters and immune function. Fallahpour *et al*. (2017) studied the effects of marshmallow extract (*Althaea officinalis*) as a natural replacement for chemical drugs in aquaculture, concluding that it is approved as a preclinical treatment based on blood cell and some liver enzyme functions. Gholipourkanani *et al*. (2017) found carp young with a diet supplemented by lemon bee brush (*Lippia* (= *Aloysia*) *citrodora*) essential oil increased in weight, had the lowest haemoglobin and haematocrit indices and lower lipid and ash content. Jafari Kenari *et al*. (2017) found that a bath in *Aloe vera*, a pharmaceutical plant, had a better influence on tissue recovery and blood factors for fish exposed to the pesticide diazinon than dietary *Aloe vera*. Khani *et al*. (2017) added dry, powdered *Chlorella vulgaris* microalga to the diet of koi and at 5% haematological parameters were increased and the immune system

stimulated. Nejatsanati and Zamini (2017) found that oral administration of extracts of 1% chamomile (*Matricaria recutita*) and later 1% fennel (*Foeniculum vulgare*) improved haematological and immune parameters of fingerlings. Rashidi *et al*. (2017) found that serum of fish fed with 3% nettle extract (*Urtica dioica*) had a significant difference in level of aspartate transaminase, a liver enzyme, compared to controls. Visi *et al*. (2017) concluded that an aqueous extract of propolis (bee glue) is not an appropriate dietary option for stimulating blood indices in carp. Ahmadnezhad *et al*. (2018) showed that cell phone electromagnetic waves produced numerous negative biological effects on koi broodstock including haematological and reproductive ones. Kahkesh and Roomiani (2018) evaluated the effects of dietary synbiotic *Lactobacillus casei* and the prebiotic immunogen on immunological and haematological parameters of juveniles, finding the best results were from 1% immunogen with the synbiotic. Mohammadi *et al*. (2018) studied the effects of ethanolic extract of *Lawsonia inermis* (henna) baths on haematological parameters, finding variation in red and white blood cell counts, haematocrit and haemoglobin values, among others. Saremi *et al*. (2018) showed high doses (1.5%) of cumin seed (*Cuminum cyminum*) ethanolic extract in the diet improved fingerling serum parameters and digestive enzyme activity. Jafaryan *et al*. (2019) found feeding juveniles with *Bacillus* sp. probiotics (protexin) had positive effects on blood parameters before and after long-distance transportation in plastic bags.

Ghiasi *et al*. (2020) studied the effect of overwintering with its decrease or lack of food on haematological and some sero-immunological parameters in cultivated carp. They recommended the use of high-quality diets and immunostimulants to increase haemato-serological parameters and immunity, and increasing water temperature and starting fish feeding actively. Homayouni *et al*. (2020) administered betaine and natuzyme multi-enzyme to the diet of juveniles and found improved blood biochemical and immune parameters. Mohammadian *et al*. (2020) administered the common myrtle (*Myrtus communis*) essential oil to carp and the effects on biochemical and antioxidant parameters were not abnormal or affected by stressful conditions so this feed additive did not affect fish health. Shirmohammadi and Mohammadnejad (2021) showed that weight changes, from 500 to 2,000 g, did not affect haematological indicators and some biochemical indicators in carp blood serum.

*Stress:-*

Nematollahi *et al*. (2006) studied the stress response during and after confinement in 17α-hydroxylase deficient carp and found the head kidney somatic index was larger and cortisol, corticosterone and lactate levels were significantly different from normal fish, the reduced cortisol output leading to increased stimulation of the adrenals by ACTH giving increased output of corticosterone. Nematollahi *et al*. (2013) found a reduced capacity of sick fish to produce the hormone cortisol (the primary activator of anti-stress pathways) was caused by a deficiency in 17α-hydroxylase activity.

Namatollahi (2010) found stress responses to confinement were similar to other fish species. Moini *et al*. (2011) measured stress responses and meat qualities after fish were stunned by ice asphyxia, air asphyxia and immersion in clove oil, the latter being best. Shabanpour *et al*. (2011) showed overcrowding and asphyxia caused maximum stress and reduced flesh quality. Hosseini and Hoseini (2012) found acute crowding stress in juveniles, which are hyperosmotic regulators, after exposure to a saline medium and that crowding does not impair the osmotic stress response. Hosseini and Hoseini (2013) used tryptophan in the diet to reduce stress in farmed fish when handled or in crowded conditions. Paighambari *et al*. (2013) studied the effects of electrofishing stress on haematological parameters and found an

increase in white blood cells but no other parameters.

Beikzadeh Takori *et al*. (2015) found that oral treatment with cortisol-controlled damage in gill tissue subjected to stress (12 p.p.t. salinity for seven days), chloride cells increased and better osmoregulation resulted. Ehsani Kenari *et al*. (2015) examined the stress effects of transportation of broodstock from ponds to hatcheries in three intervals - immediately after capture, two hours for transfer and 24 hours after transportation. Stress indicators such as levels of cortisol, sex steroids and some blood factors were elevated after capture but fell over time. Ghiasi and Falahatkar (2015) found injection of juveniles with cortisol (which is released naturally in response to stress) negatively affected food intake and growth. Ranjdoust *et al*. (2016, 2018) studied the effects of celmanax liquid yeast as a diet supplementation on biochemical parameters during long-distance transportation (over 12 hours) of juveniles, finding reduced stress. Azar *et al*. (2017) studied the effect of stevia or candyleaf (*Stevia rebaudiana*) extract on growth and survival under stress due to crowding in juveniles, finding fish stocked at 3 kg/cu m and fed stevia had higher values in all growth parameters. Dehghani Ghomshani *et al*. (2017) found that adding safflower (*Carthamus tinctorius*) extract to the diet of fingerlings improved salinity stress tolerance. Mohiseni *et al*. (2017) supplemented the diet of juveniles with Shirazi thyme (*Zataria multiflora*) and vitamin E led to significant protection against cadmium exposure in different tissues. Moreover Shirazi thyme was found to be as effective as vitamin E and stress protective. Roohi *et al*. (2017) supplemented the diet of fingerlings with caraway or Persian cumin seeds (*Carum cari*) which had a positive influence on the glucose and haematocrit levels and resistance to salinity stress. Soleimanirad (2017) found the optimal stocking density of juvenile koi carp was 150 fish per cubic metre as higher densities caused growth reduction and stress. Sudagar (2017a) showed that dietary turmeric (*Curcuma longa*) at more than 1.0% reduced growth of fingerlings but increased resistance against salinity stress. A dosage of 0.5-1.0% was recommended. Gharacheh (2018) found electrofishing of wild common carp was stressful with effects on body homeostasis as shown by serum biochemical and haematological factors. Mohiseni *et al*. (2018) found using Shirazi thyme and vitamin E as complementary additives in the diet of fingerlings improved stress responses to cadmium exposure. Chaharborji *et al*. (2019) exposed fish to various concentrations of spearmint essential oil and found 10 μl/l could reduce stress in transport. Ghelichpour (2019) noted that the addition of 3 g/l of salt to transportation water was beneficial as it mitigated water quality deterioration, stress responses, hydromineral imbalance and immunosuppression. Hoseini *et al*. (2019b) recommended using sodium chloride during fish recovery from transportation, particularly when the fish were transported at high stocking density. The benefits of sodium chloride treatment were likely mediated by restoration of hydromineral balance and oxidative status, which led to healthier fish with higher immune responses. Changes in water transport quality and fish biochemistry were documented. Jafari *et al*. (2019) concluded that the amino acid glycine in the diet improved resistance and could increase survival of young carp under salinity stress, but not most growth indices. Jafari *et al*. (2019) showed that arginine at 1.5-2.0% in the diet of fingerlings had significant effects on body immunity and survival. Mazandarani *et al*. (2019) found the addition of 0.5-3.0% safflower (*Carthamus tinctorius*) extract to the diet increased resistance to salinity challenge and mitigated stress. Ranjdoust *et al*. (2019) studied the use of celmanax (a liquid yeast prebiotic) and a blend of five probiotic bacilli (*Bacillus circulans, B. laterosporus, B. licheniformis, B. polymyxa, B. subtilis*) in long-time transportation at different salinities and found a reduction in stress.

Taziki *et al*. (2021) showed that including two amino acids, L-proline and L-alanine, at a combined level of 0.5 + 0.5% in the diet can be effective in improving haematological and survival parameters in the face of salinity stress in juvenile carp.

*Anaesthesia:-*

Peyghan *et al*. (2001) studied the use of ketamine and xylazine hydrochloride as anaesthetics. Abtahi *et al*. (2002) found clove oil had no significant difference with MS-222, another anaesthetic used in fish farms. Fathiazad *et al*. (2002) showed clove oil to be a suitable substitute anaesthetic for MS-222 (which has side effects and 21-day withdrawal period) in juvenile *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*. Sharifpour *et al*. (2003) also studied the anaesthetic effects of clove oil under various pH and temperature regimes and Soltani *et al*. (2004) examined the effects of clove oil on haematological parameters, serum enzymes and some tissues, up to 200 p.p.m. being deemed safe.

Rahmanifarah *et al*. (2010) found stunning and killing fish with clove oil preserved the flesh quality better than other methods such as carbon dioxide bath and asphyxia. Sudagar *et al*. (2011) used electricity to slaughter fish for consumption and studied the effects on meat quality. Paykan Heyrati *et al*. (2012) and Paykhan Herati *et al*. (2012) measured haematological responses to the use of clove powder as an anaesthetic, the recommended dose being 500 p.p.m. Shabanpour *et al*. (2012) found slaughtering fish by hypothermia as opposed to exsanguination or asphyxia led to a higher flesh quality. Ghelichi *et al*. (2013) found the use of the anaesthetic lidocaine in simulated transport of fingerlings showed decreased oxygen consumption and ammonia excretion while there were no significant differences in haematological parameters. Hosseinie and Hoseinie (2013) examined the correlation between stress indicators and anaesthesia time under different clove solution concentrations and found it best to reduce anaesthesia duration to less than one minute to prevent stress. Keyhani Seyyed *et al*. (2013) used *Pterocarya fraxinifolia* (Caucasian walnut) extracts and essences as an anaesthetic, a methanolic extract at 200 p.p.m. concentration, 25°C and pH 7-8 being best. Yeganeh and Maleki (2013) investigated the anaesthetic effects of lemon balm (*Melissa officinalis*), sage (*Salvia officinalis*) and valerian (*Valeriana officinalis*) on juveniles, finding differences significantly reduced at higher concentrations and various recovery times with various concentrations. Alishahi *et al*. (2014, 2014) found that the anaesthetics MS-222 and clove oil had no adverse effects on immunological parameters while 2-phenoxyethanol caused light immunosuppression and could not be recommended. MS-222 was the most efficacious and safe.

Beheshti *et al*. (2018) found lavender (*Lavandula angustifolia*) essential oil had an $LC_{50}$ 96 h of 99.7 mg/l to juveniles and could be used as an anaesthetic at 170 mg/l for 3.74 minutes with full recovery after 3.91 minutes. Beheshti *et al*. (2018b) compared lavender oil (*Lavandula angustifolia*) and clove oil as anaesthetics in aquaculture, finding that the former could be used to replace the latter. Rakhshani *et al*. (2018) studied the anaesthetic vigour and histopathological effect of peppermint oil (*Mentha piperita*) on juveniles, finding 200 p.p.m. was an effective and safe level of usage. Yousefi *et al*. (2018) showed that citronellal was more efficacious (less tissue problems) for juveniles than linalool in short- and long-term anaesthesia and for long-term anaesthesia than eugenol. Bahrekazemi (2019) investigated the anaesthetic effects of sodium bicarbonate, 2-phenoxyl ethanol, clove extract and thyme extract and found the lower stressful effects were with clove and thyme extracts and negative irreversible effects were not observed with 2-phenoxy ethanol.

Hoseini *et al*. (2020) found anaesthesia with 1,000 μl/l 1,8-cineole cineole (eucalyptol, a compound of plant essential oils) was suitable for rapid sampling, but not for practical aquaculture, and anaesthesia led to an apparent increase in innate immune responses, which may have been a defensive response to anaesthesia-induced stress.

**Conservation.** Vladykov (1964) recommended that fishing for this species in Mazandaran and Gorgan be prohibited for five years because of reduced stocks. Krasznai (1987) and Petr (1987) gave details of fish farms propagating this species in Iran. For example, 30 million fish were produced by the Sefid Rud Fish Farm in 1986. In 1999-2000, 20 million juveniles were released into the Caspian Sea (*Iranian Fisheries Research Organization Newsletter*, 23:4, 2000). From October to March 2000, 3 million juveniles raised in the Shahid Ansari aquaculture and breeding centre in Gilan were released into the Caspian Sea and neighbouring water bodies (*Iranian Fisheries Research Organization Newsletter*, 26:2, 2001).

Moghaddas *et al*. (2021) noted that wild forms of this fish have declined dramatically in the Anzali Wetland as a result of elevated fishing pressure and unfavourable spawning conditions. The domesticated carp was ranked as a high-risk species in the Wetland as it could genetically contaminate wild populations and detrimentally impact the aquatic ecosystem.

Poaching was a problem in the Caspian basin of Iran (Razivi *et al*., 1972) and no doubt continues.

The Atrak River stocks are an important fishery for both Iran and Turkmenistan but are susceptible to loss through the absence of flooding of the spawning grounds. Fish passes are needed to ensure access to the spawning grounds, timely release of water from a reservoir to flood the spawning areas in years of low water flow, enforcement of catch limits, and continued stocking (Petr, 1987).

Vazirzadeh and Yelghi (2015) examined fish from the southeastern Caspian Sea and compared their study with results from five decades previously, observing that replacing gill nets with beach seines had positive effects on growth and age composition of the wild common carp. Catches in 1993 were dominated by two- to three-year-old fish (and fish matured at 3 years) but recent catches were older. Vazirzadeh *et al*. (2016) mentioned that the fishery for wild common carp in the Iranian Caspian Sea basin was underpinned by release of cultured juveniles, and the species was threatened by overexploitation, damming of rivers, and degradation of spawning grounds.

The studies of Ghelichpour *et al*. (2011, 2013) mentioned above, showing different populations with great allelic richness, have implications for conservation and management. Yousefian (2011a) found low heterozygosity using five microsatellite loci, perhaps indicative of overfishing, such information being important in managing the stocks. Mousavi-Sabet *et al*. (2018b) compared wild and farmed fish and were able to distinguish them morphometrically, useful for selecting broodstocks for a restocking programme.

Masompour *et al*. (2018) found this species in ghost nets in the Caspian Sea between Babolsar and Sorkh Rud over 200 sq km of Mazandaran coastline. A total of 515 gillnet panels were removed with an estimated total length of 30.9 km and an average mesh size of 80 mm. It was the third most caught species in fall of 12 recorded but only six fish were recorded. One fish was caught in winter. For comparison 187 *Alosa caspia* (Caspian shad) were caught in winter.

Lelek (1987) considered that the wild form, as opposed to domestic stocks, was vulnerable to endangered in Europe because of habitat modifications. Kiabi *et al*. (1999) considered this species to be of least concern in the south Caspian Sea basin according to

IUCN criteria. Criteria included commercial fishing, sport fishing, abundant in numbers, habitat destruction, widespread range (75% of water bodies), present in other water bodies in Iran, and present outside the Caspian Sea basin. Listed as Vulnerable by the IUCN (2015) for native populations due to river regulation and hybridisation with domesticated stocks.

**Sources.** Iranian material:- CMNFI 1970-0509, 1, not kept, Gilan, Sefid River at Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1970-0510, 1, 47.8 mm standard length, Gilan, Golshan River (37º26'N, 49º40'E); CMNFI 1970-0521, 1, not kept, Gilan, Sefid River near Lulaman (no other locality data); CMNFI 1970-0522, 1, 108.5 mm standard length, Gilan, Sefid River at Astaneh Bridge (37º16'30"N, 49º56'E); CMNFI 1970-0548, 1, not kept, Golestan, Qareh Su (no other locality data); CMNFI 1970-0563, 3, 28.6-58.6 mm standard length, Gilan, Caspian Sea at Kazian Beach (ca. 37º29'N, ca. 49º29'E); CMNFI 1970-0568, 1, 125.8 mm standard length, Gilan, Caspian Sea at Kazian Beach (ca. 37º29'N, ca. 49º29'E); CMNFI 1970-0582, 3, 63.3- 134.0 mm standard length, Golestan, Aliabad Reservoir (*sic*) (36º56'N, 54º50'E); CMNFI 1970-0587, 2, 47.5-76.7 mm standard length, Mazandaran, Babol River at Babol Sar (36º43'N, 52º39'E); CMNFI 1979-0431, not kept, Mazandaran, bazaar at Now Shahr (no other locality data); CMNFI 1979-0455, 6, 46.9-67.1 mm standard length, Qazvin, Manjil Dam (36º45'N, 49º17'E); CMNFI 1979-0476, 3, 44.1-85.3 mm standard length, Golestan, Qareh Su near Kord Kuy (36º51'N, 54º05'E); CMNFI 1979-0479, 19, 28.0-143.8 mm standard length, Golestan, dam on Gorgan River (37º09'30"N, 54º41'30"E); CMNFI 1979-0685, 2, 31.5-45.7 mm standard length, Gilan, Sefid River (ca. 37º22'N, ca. 49º57'E); CMNFI 1979-0788, 2, 104.2-123.5 mm standard length, Golestan, Gorgan River at Khadje Nafas (37º00'N, 54º07'E); CMNFI 1980-0128, 3, 60.2-75.2 mm standard length, Golestan, Qareh Su (36º49'30"N, 54º03'30"E); CMNFI 1980-0132, 4, 56.0-64.6 mm standard length, Gilan, Sefid River at Kisom (37º12'N, 49º54'E); CMNFI 1980-0157, 1, 126.3 mm standard length, Golestan, Gorgan River estuary (36º59'N, 53º59'30"E); CMNFI 1980-0905, 2, 78.1-92.9 mm standard length, Golestan, Gorgan River at Khadje Nafas (37º00'N, 54º07'E); CMNFI 1980-0908, 1, 54.4 mm standard length, Gilan, Sefid River estuary (ca. 37º28'N, ca. 49º54'E); CMNFI 2008-0151, 1, 101.5 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); CMNFI 2008-0163, not kept, Khuzestan, Marun River at Chahar Asiab (30º40'28"N, 50º09'34"E); CMNFI 2008-0178, not kept, Khuzestan, Karun River at Ahvaz (31º19'N, 48º42'E); CMNFI 2008-0204, 1, 103.9 mm standard length, Sistan (no other locality data).

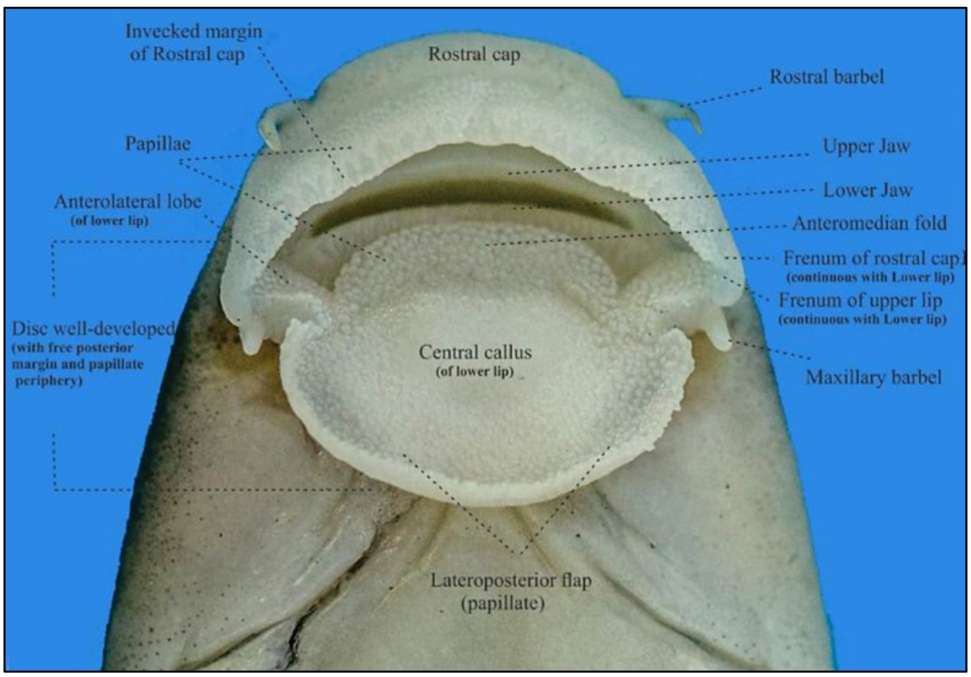
## Genus *Garra*

Hamilton, 1822

The genus *Garra* is found throughout Southwest Asia and from Africa to Southeast Asia. There are about 129 species and at least 15 species are present in Iran. The genera *Discognathus* Heckel, 1843, *Discognathichthys* Bleeker, 1860, *Hemigrammocapoeta* Pellegrin, 1927 and *Iranocypris* Bruun and Kaiser, 1944 are synonyms. Hora (1921) presented anatomical arguments for including *Discognathus* in *Garra*. Zamani-Faradonbe and Keivany (2021a) reviewed the biodiversity and distribution of Iranian species based on 2,970 specimens from 233 stations.

This genus is characterised by a small to moderate-sized body, elongate and almost cylindrical, a rounded snout with the mouth inferior and crescent-shaped, the lower jaw has a horny edge, the upper lip is usually fringed and continuous with the snout, the lower lip and chin area are usually modified in most species into a suctorial or mental disc with free posterior

margin (elsewhere some have a callous pad according to Stiassny and Getahun (2007), some species have a reduced disc, the smallest specimens lack full disc development and, with *Hemigrammocapoeta* species included, the disc is absent and the chin area is weakly papillose - evolution and reduction of the disc occurred independently in 6-7 lineages (Behrens-Chapuis *et al*., 2015; Hashemzadeh Segherloo *et al*., 2017)), the anterior disc margin is free or adherent (species with the latter condition were placed in a separate genus, *Discognathus* or *Discognathichthys*), usually one or two pairs of short barbels (species with the former condition were placed in a separate genus, *Discognathus* or *Discognathichthys*), vomero-palatine organ vestigial or regressed, supraethmoid wider than long in dorsal aspect, cleithrum narrow and anteriorly elongate, eyes small, usually large scales, lateral line complete, small dorsal and anal fins without thickened rays, pectoral and pelvic fins placed horizontally on the body, first two or more pectoral fin rays prominent and often unbranched, pharyngeal teeth in three rows (typically 2,4,5-5,4,2) with hook-shaped tips and spoon-shaped crowns, vent may be midway between pelvic and anal fin bases or nearer the latter, elongate and coiled gut, a black peritoneum, and 2n = 50.




Mouth region of *Garra amirhosseini*, Hamid Reza Esmaeili.

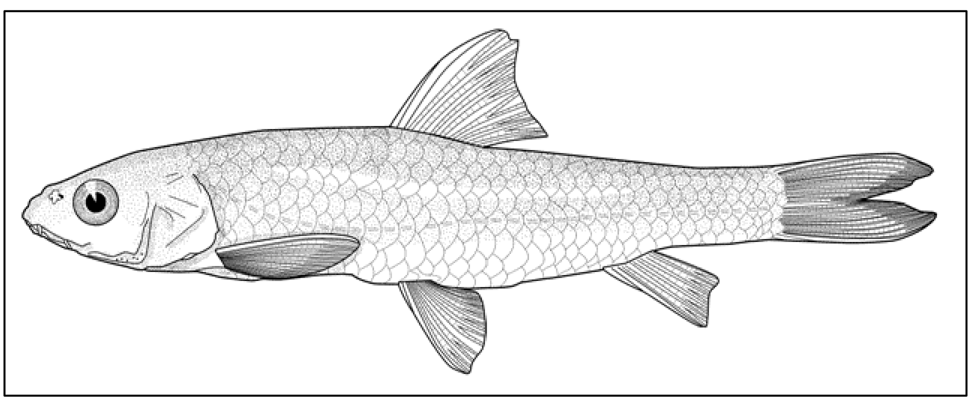
Hashemzadeh Segherloo *et al*. (2017) found the Middle Eastern species of *Garra* form two major clades, clade I including *G. rossica* and *G. variabilis* in Iran and clade II the other species. Clade I probably diverged from some Asian species of *Garra* about 12 Ma (million years ago) and from clade II around 15.7 Ma. *G. rossica* and *G. variabilis* are thought to be related, as Menon (1964) suggested, based on the small and poorly structured mental disc. *G. gymnothorax*, *G. lorestanensis* and *G. typhlops* form a sub-clade and showed a high level of mtDNA divergence that may be due to habitat isolation of the latter two species which are cave fishes. The two cave fishes inhabit the same cave system and probably resulted from two different colonisation events. Another sub-clade included a non-disc bearing *G. cf. persica* from the Kesh River in the Makran basin (see under *G. persica*) and *G. persica*. Another sub-

clade included *G. elegans* (in Iraq, see Freyhof (2016)), *G. mondica* and *G.* sp. (Kul River basin) which presumably colonised the wide range of distribution from the Tigris to the Kul basins during the last ice age via watershed confluence events in the Persian Gulf. A final sub-clade comprises *G. rufa*. These authors also detailed relationships between Iranian species and others in the Middle East.

Sungur *et al*. (2020) found *Garra* to be a monophyletic group using caudal osteology but could not distinguish species because of the small number of extractable characters and their states.

The recent description of two new species of *Garra* from Iran is particularly interesting. Other new species are from unique habitats, e.g., *G. tashanensis* from a cave, or have unique morphology, e.g., *G. roseae* lacking barbels. The two new species, *G. meymehensis* and *G. tiam*, are defined principally by DNA, morphology falling within that for the related, morphologically diverse and widespread *G. rufa*, differing only in "a combination of characters, none of them unique to the species". Elsewhere in the current work, many cyprinoid species show differences in morphology between rivers attributed to adaptation to their differing habitats rather than species-level differentiation. The two river habitats (Meymeh and Ab-e Shur rivers) of the two new species are not isolated from the general range of the related *G. rufa* and do not appear to be unique in any way. Do other rivers then harbour new and cryptic *Garra* species? Plausibly, there could be many new species based on DNA evidence or perhaps DNA evidence based on a single gene is misleading and other genes need to be examined to garner a fuller and more rigorous picture of diversity or the lack thereof.

*Garra elegans* (Günther, 1868) (gel cheragh-e ziba or elegant Garra) may be present in Iran but this has not been confirmed.



*Garra elegans*, Susan Laurie- Bourque @ Canadian Museum of Nature.

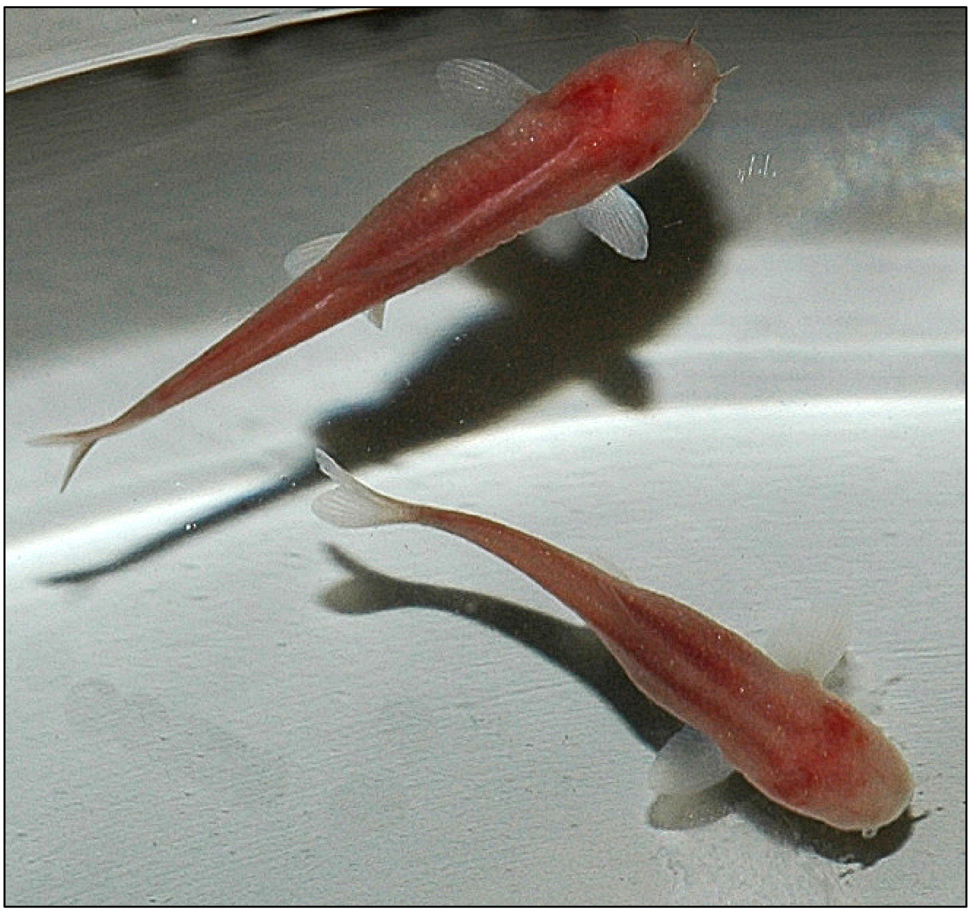
The Farsi common name used generally for these fishes is gel cheragh (= mud-eater, mud-grazer), mahi sangi and mahi sang lis (= rock or stone fish, slippery rock fish), not always repeated in each Species Account.

Some species are found in mountains streams and other flowing waters, maintaining position with their suctorial disc, reduced gas bladder, flattened belly and large, splayed and horizontal paired fins. *Garra barreimiae* from the United Arab Emirates has been filmed scaling a waterfall (Majeed *et al*., 2019). Other species are known to occur in slow-moving or stagnant waters and here have a reduced or absent mental disc. They scrape algae from rocks. These are oily fishes which are eaten in India (Hora, 1956).

Menon (1954) considered that the members of this genus spread westwards along the

Himalayas as late as the early Pleistocene. Kosswig (1952) indicated their presence in the Araxes (= Aras) of Turkey but this seems to an error. Interestingly, Vasilyan and Carnevale (2013) found fossil *Garra* in the late Miocene (not Pliocene as in the paper, D. Vasilyan, pers. comm., 10 April 2018) of Central Armenia suggesting that the Aras-Kura River drainage was connected, at least in part, with the Tigris-Euphrates drainage at this time. Extinction of *Garra* from the Aras-Kura was probably due to Plio-Pleistocene tectonic uplift of the Armenian Highland and progressive climate cooling.

A collection of a cave fish from a tunnel at dam site now covered in cement was documented by Mahjoorazad and Coad (2009) and Coad (2019a). This taxon was not identified to species and may in fact be new. The available material is small and in poor condition. DNA analysis failed to work because of time and preservation state. The collection is under CMNFI 2008-0231, 2 fish, 17.4-19.3 mm standard length, Lorestan, Simareh River (33°16'56"N, 47°12'16"E).



Lorestan, Simareh cave fish, not kept, Atabak Mahjoorazad.

The following table summarises some key distinguishing characters of the Iranian species of *Garra*. Several species have very restricted or widely-separated distributions and distribution is often key.

| Species/ Characters | Modal dorsal fin branched rays | Modal caudal fin branched rays | Mental disc | Ventral scales | Barbels | Colour and eyes | Distribution |
|---|---|---|---|---|---|---|---|
| *G. amirhosseini* | 7 | 17 | Present, well-developed | Very small, embedded | 4 | Pigment and eyes present | Sartang-e Bijar Spring, Tigris River |
| *G. gymnothorax* | 8 | 17 | Present, well-developed | Naked or embedded | 4 | Pigment and eyes present | Tigris River |
| *G. lorestanensis* | 7-8 | 17 | Present, well-developed | Naked | 4 | No pigment or eyes | Loven Cave and Tuveh Spring, Tigris River |
| *G. meymehensis* | 7 | 17 | Present, well-developed | Breast embedded, belly scaled | 4 | Pigment and eyes present | Meymeh River, Tigris River |
| *G. mondica* | 7 | 17 | Present, well-developed | Naked breast and belly | 4 | Pigment and eyes present | Persis |
| *G. nudiventris* | 7 | 17 | Present, weakly-developed | Usually naked | 2 | Pigment and eyes present | Lut, Makran, Sistan, possibly Bejestan and Jaz Murian |
| *G. persica* | 7 | 16 | Present, well-developed | Present, embedded on breast | 4 | Pigment and eyes present | Hormuz, Jaz Murian, Makran, possibly Kerman-Na'in and Sistan |
| *G. roseae* | 7 | 17 | Present, well-developed | Breast naked, belly scaled | Absent | Pigment and eyes present | Tang-e Sahre Stream, Makran |
| *G. rossica* | 7 | 17 | Present, weakly-developed | Present, embedded | Usually 2 | Pigment and eyes present | Bejestan, Hari, Jaz Murian, Lut, Makran, Mashkid, Sistan |
| *G. rufa* | 8 | 17 | Present, well-developed | Present or absent | 4 | Pigment and eyes present | Hormuz, Maharlu, Persis, Tigris |
| *G.* sp. Kul River | 7 | 17 | Present, well-developed | Present | 4 | Pigment and eyes present | Hormuz |
| *G. tashanensis* | 7 | 17 | Present, well-developed | Naked | 4 | No pigment or eyes | Tashan Cave, Tigris River |
| *G. tiam* | 8 | 17 | Present, well-developed | Breast naked, belly scaled | 4 | Pigment and eyes present | Ab-e Shur, Tigris River |
| *G. typhlops* | 7-8 | 17 | Absent | Naked | 4 | No pigment or eyes | Loven Cave and Tuveh Spring, Tigris River |
| *G. variabilis* | 7 | 17 | Present, weakly-developed | Present | Usually2 | Pigment and eyes present | Tigris River |

## ***Garra amirhosseini***
Esmaeili, Sayyadzadeh, Coad and Eagderi, 2016

*Garra amirhosseini*, holotype, ZM-CBSU H1216, Hamid Reza Esmaeili.

*Garra amirhosseini*, holotype, ZM-CBSU H1216, Hamid Reza Esmaeili.

*Garra amirhosseini*, holotype, ZM-CBSU H1216, Hamid Reza Esmaeili.

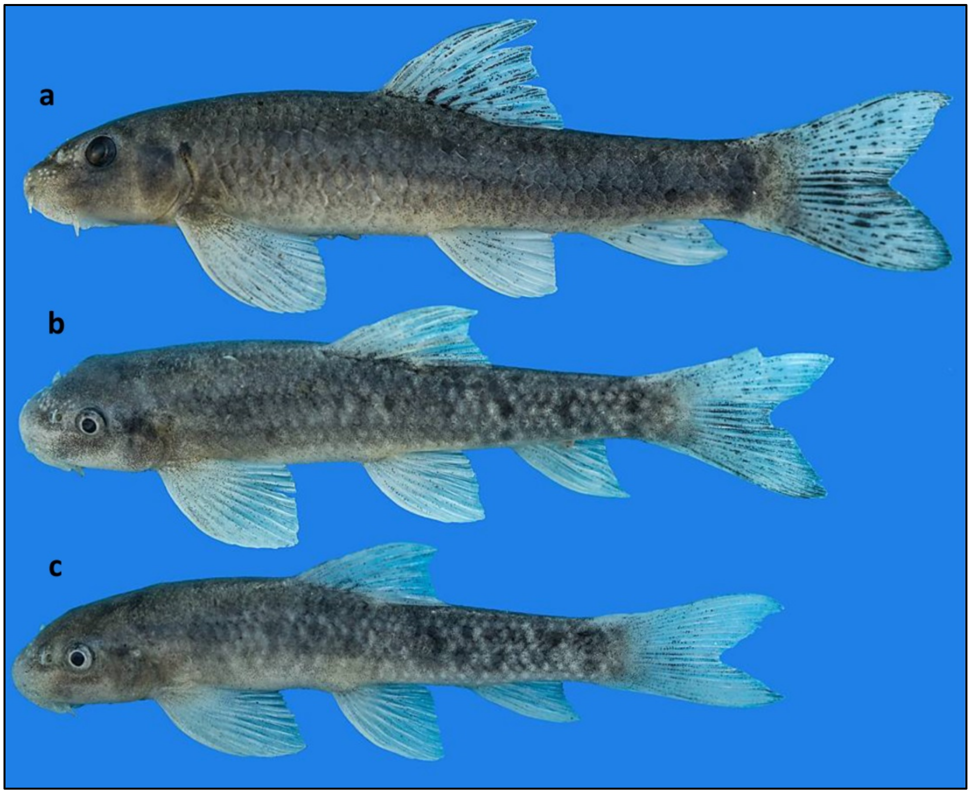
**Common names.** Gel cheragh Amirhossein (Amirhossein's mud-eater), gel cheragh-e ab-e garm (= hot spring mud-eater).

[Amirhossein's garra, Amirhossein's stone lapper, hot spring garra].

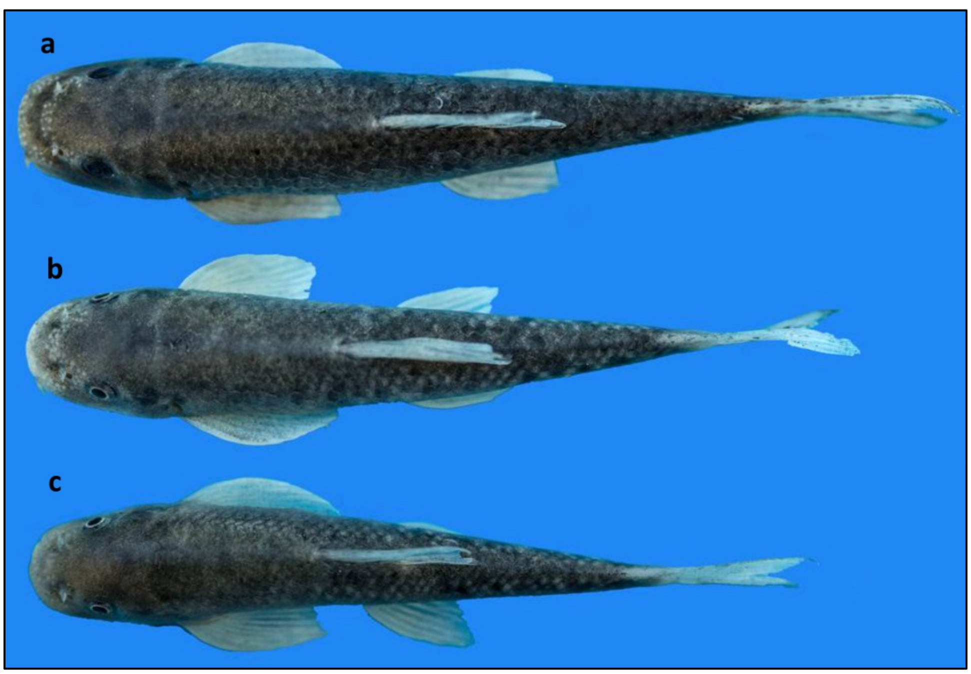
**Systematics.** The holotype is 67.3 mm standard length from Ilam, Sartang-e-Bijar hot spring at Mehran, Tigris River drainage, 33°46'16.3"N 45°56'17.2"E (ZM-CBSU H1216 (Zoological Museum of Shiraz University, Collection of Biology Department, Shiraz)) and paratypes are under ZM-CBSU H1217, 6, 46-66 mm standard length same data as holotype and ZM-CBSU J2791, 22, 40-60 mm standard length, Ilam, Sartang-e-Bijar hot spring at Mehran, Tigris River drainage, 33°46'19.1"N 45°56'19.0"E. ZM-CBSU H1219 and 1220 are also paratypes according to the figures. The species is named after the son of the first author.

*Garra amirhosseini*, holotype, ZM-CBSU H1216, Hamid Reza Esmaeili.

*Garra amirhosseini*, holotype, ZM-CBSU H1216, Hamid Reza Esmaeili.




*Garra amirhosseini*, paratypes, a, 66.4 mm standard length, ZM-CBSU H1217, b, 58.9 mm standard length, ZM-CBSU H1219, c, 54.9 mm standard length, ZM-CBSU H1220, Hamid Reza Esmaeili.




*Garra amirhosseini*, paratypes, as above, Hamid Reza Esmaeili.

*Garra amirhosseini*, paratypes, as above, Hamid Reza Esmaeili.

**Key characters.** This species is distinguished from all other species of *Garra* in the rivers flowing to the Persian Gulf by having the breast and belly with very small scales which are fully covered by a thick epidermal layer (versus a naked breast in *G. gymnothorax*, naked breast and belly in *G. mondica*, or fully covered by normal scales without any covering layer), and modally 7 dorsal fin branched rays. The species is restricted to a hot spring.

**Morphology.** The body is elongated, moderately compressed laterally, and more compressed in the region of the caudal peduncle. The dorsal head profile rises gently, being flat or slightly convex, more or less continuous with dorsal body profile, to the nape or about the middle between the nape and the dorsal fin origin. The ventral profile is more or less straight to the anal fin origin. The head is moderately large and depressed, with a slightly convex or flat interorbital distance. The depth at the nape is less than the head length. The width at the nape is greater, or about equal to, the depth at the nape. The snout is rounded. The rostral cap is well-developed, fimbriate, and papillate on the ventral surface. The upper jaw is almost or completely covered by the rostral cap. The upper lip presents as a thin band of papillae arranged in two ridges. The proboscis is not, or only slightly, elevated from the depressed rostral surface. The anterior arm of the depressed rostral surface does not reach to the base of the rostral barbel, clearly separating the transverse lobe from the lateral surface in large specimens. There is no groove between the transverse lobe and the lateral surface in some individuals. The eye is placed dorso-laterally in the anterior half, or about the mid-region, of the head. Barbels are in two pairs, the rostral barbel anterolaterally located, shorter or about equal to eye diameter, and the maxillary barbel at the corner of the mouth, shorter than the rostral barbel. A well-developed disc with free lateral and posterior margins is present and is heavily papillated with batteries of fleshy papillae arrayed around the periphery of the whole disc. The disc is elliptical, shorter than wide and narrower than the head width through the base of the maxillary barbel. Papillae on the anterior fold are of the same size, regularly arranged. A groove between the antero-median fold and the central callous pad is narrow and deep. Papillae on the inner half of the whole length of the latero-posterior flap are coarsely arranged. The

anterior marginal surface of the central callous pad is without, or with, sparsely arranged small papillae. The posterior margin of the latero-posterior flap extends back to the vertical of the middle of eye. The last dorsal fin unbranched ray is slightly shorter than head length and the first branched ray is longest. The distal margin of this fin is concave. The origin of the dorsal fin is closer to the snout tip than to the caudal fin base and is anterior to the vertical from the pelvic fin origin. The tip of the last dorsal fin branched ray reaches the vertical from the anus. The caudal fin is forked with pointed tips. The anal fin is short with the first branched ray the longest, the distal margin is straight or slightly concave, and the origin lies closer to the pelvic fin origin than to the caudal fin base. The pelvic fin reaches to the anus, the origin closer to the anal fin origin than to the pectoral fin origin, and the origin is below the second or third branched dorsal fin ray. The pectoral fin reaches to a point 3-4 scales anterior to the pelvic fin origin, and its length is shorter, or slightly equal, to head length. The anus is 2-3 scales in front of the anal fin origin.

Dorsal fin unbranched rays 3, branched rays 7, anal fin unbranched rays 3, branched rays 5, pectoral fin branched rays 12-13, and pelvic fin branched rays 7-8. Lateral line complete, with 33(4), 34(3), 35(4) or 36(4) scales on the body and 2-3 scales on the caudal fin base. Transverse scale rows above the lateral line are 3-4, scales between the lateral line and the pelvic fin origin 3, and scales between the lateral line and the anal fin origin 3. Scales around the caudal peduncle number 13-14. Usually, 17-19 scales are on the predorsal midline between the dorsal fin origin and the nape, deeply embedded in many individuals and uncountable. Scales on the flank are regularly arranged. The chest and belly have very small scales which are fully covered by a thick epidermal layer. There is one short axillary scale at the base of the pelvic fin in some individuals, and 5-7, usually 5, scales between the posteriormost pelvic fin base and the anus, embedded in the skin in some individuals. Total gill rakers 16(5), 17(7), 18(2), 19(-) or 20(1).

**Sexual dimorphism.** Males have the lateral surface of the snout covered by 6-18 small-sized tubercles running in a band across the lower snout and reaching back to the anterior eye margin in some individuals, or to the posterior nostril in others, largest on the anterior margin of the proboscis. These tubercles are demarcated posteriorly by a slightly shallow transverse groove in some individuals, and no transverse groove in others. The depressed rostral surface is always without tubercles.

**Colour.** Preserved fish have the head, back and upper flanks dark grey to brown. Back and flank pigment can be dense and continuous or splotchier with some scales quite light. Dark colouration may extend onto the lower flank or the lower third to almost half of the flank is pale. There are single or groups of dark scales on the flank. A very faint, irregularly-shaped mid-lateral stripe is restricted to the posterior flank or absent in some individuals. The mouth, chest and abdomen are yellowish-white. There is a wide black or dark brown bar at the posteriormost caudal peduncle, faded in some individuals, bold and 2-3 scales wide in others. The bar reaches the dorsal midline in most individuals, not reaching the ventral midline. There is a small black blotch at the anteriormost lateral line. Lateral line pores are cream whitish. The dorsal, caudal and anal fins have irregularly set black spots or extended lines of dark pigment on rays with some pigmentation on membranes, or rays are partly dusty grey or black. The base of the last 2-6 dorsal fin branched rays has a black spot or an extended line of pigment, more prominent in rays 3- 5. Paired fins are finely speckled, densely in some fish, sparsely in others, and sometimes densely on membranes. In life, the fins are hyaline with black spots. The head is grey. Flank scales are dark grey with individual or groups of pale grey scales forming a

mottled pattern, whitish or pale grey on the ventral flank and belly. The iris is silvery orange. There is a pale blue dot at the anteriormost lateral line, forming a faded patch reaching down to the upper pectoral fin base in some individuals.

**Size.** Reaches 67.3 mm standard length.

**Distribution.** Restricted to a hot spring about 70 km northwest of Ilam (see above) and the Godarkhosh River, Ilam. Jouladeh-Roudbar *et al*. (2020) recorded it also from Iraq, presumably based on the drainage. Zamani-Faradonbe and Keivany (2021a) also recorded this species from the Meymeh River but later described it with co-authors as a new species, *Garra meymehensis*.

**Zoogeography.** Bayçelebi *et al*. (2018) stated that *Garra turcica* Karaman, 1971 of southern Anatolia has this species as one of its closest relatives (along with *G. elegans* (Günther, 1868) of the Tigris River basin and *G. mondica*). See also under the genus.

**Habitat.** This species is found in a hot spring and its streams.

Habitat of *Garra amirhosseini*,
Ilam, Sartang-e Bijar hot spring at Mehran, Hamid Reza Esmaeili.

**Age and growth.** Zamani-Faradonbe *et al*. (2018) found a *b* value of 3.28 for 49 fish, 3.6-6.8 cm total length, presumably from the type locality.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

**Economic importance.** None**.**

**Experimental studies.** None.

**Conservation.** Known only from a single spring, it is easily threatened by localised events. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern however based on high population numbers and no known widespread threat.

**Sources.** Esmaeili *et al*. (2016).

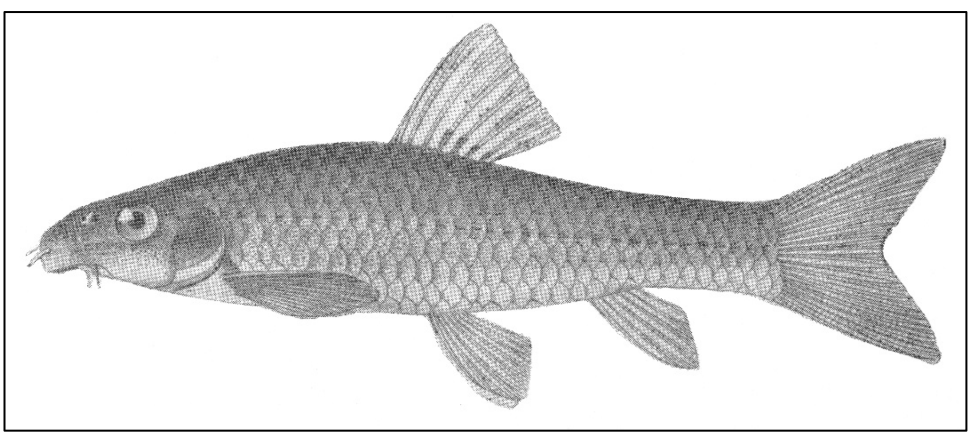
***Garra gymnothorax***
Berg, 1949

*Garra gymnothorax*, 65.4 mm standard length, ZM-CBSU H1224,
Khuzestan, Helayjan River at Izeh, Hamid Reza Esmaeili.

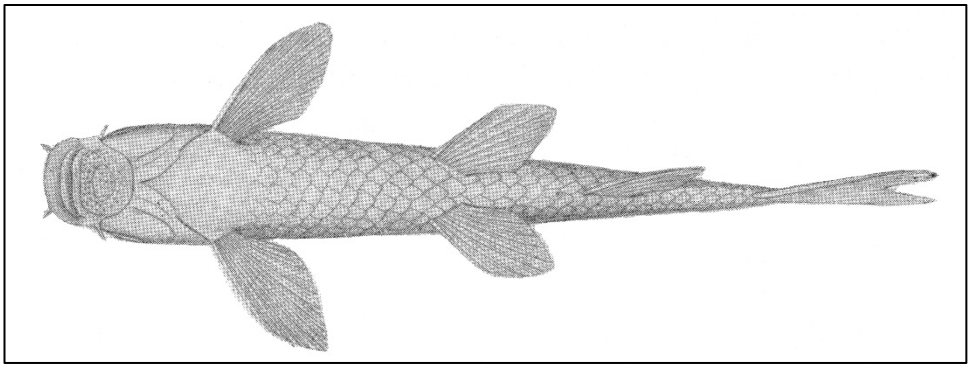
**Common names.** Gel cheragh-e shekam berahne (= naked belly mud-eater).

[Chest scaleless garra].

**Systematics.** *Garra rufa gymnothorax* Berg, 1949 was described from "Kulihan, Karun R. basin", "Malamir", "Dizful", "Ziaret-seid-hasan, Mesopotamia" and "Mendeli" (see below under **Distribution** for the first two localities). The syntypes of *Garra rufa gymnothorax* from Kulihan are in the Zoological Institute, St. Petersburg (ZISP 13214), there being six fish in the catalogue and six in the jar although Berg (1949) listed seven in his description. They measure 30.5-44.9 mm standard length. The date in Berg (1949) is 6.VI.1904 while in the catalogue it is 4.III.1904 and in the jar 24.III.1904, variations not accountable by old and new styles of dating (13 days apart). The Malamir syntypes under ZISP 13215 comprise 17 fish, 33-52 mm total length after Berg (1949). The collection from Dizful (= Dezful) comprises 1 fish 44 mm total length under ZISP 24429 after Berg (1949). ZISP 24435, Ziaret-seid-hasan (presumably from Iraq), comprises 10 fish, 37-45 mm total length after Berg (1949), is not listed as type material in the jar but the catalogue suggests that they are (Eschmeyer *et al*. (1996) listed these 10 fish as syntypes). ZISP 24436, Mendeli (= Mandali, Iraq), 3, 33-45 mm total length are also syntypes (Eschmeyer *et al*., 1996) The *Catalog of Fishes*, downloaded 15 May 2018, listed syntypes under ZISP 13214-15, (6, 6+), 24429 (1) and 24435-36 (10, 3).



*Garra rufa gymnothorax*, syntype, 4.4 cm total length, ZISP 24429,
Khuzestan, Dezful, after Berg (1949).



*Garra rufa gymnothorax*, ventral view, as above, after Berg (1949).

This species is distinguished by molecular data (Esmaeili *et al*., 2016; Kiani *et al*., 2017; Zamani-Faradonbe *et al*., 2021) with an average genetic distance between *G. rufa* and *G. gymnothorax* at 5.87% according to Kiani *et al*. (2017). Fish from the Dez, Karkheh and Karun rivers were assigned to this species but Kiani *et al*. (2017) noted that only one gene was used and, to make robust inferences, it would be better to use other genes too. The results of Zamani-Faradonbe *et al*. (2021) supported the recognition of most populations of *Garra* from the Karun and Karkheh River drainages as a clade on DNA evidence, for which the name *Garra gymnothorax* is available. *Garra gymnothorax* might be a cryptic species and additional research was recommended in order to check for morphological characters to distinguish this species from *G. rufa*. They found the squamation pattern of the chest and belly was quite variable in different populations of *G. gymnothorax* and *G. rufa* and therefore did not allow distinguishing the species. Only specimens from the Bala and Ab-e Shur rivers (both tributaries of the Karun River) exhibited a scaleless chest and belly. Morphologically, on my material, fish potentially *G. gymnothorax* are very similar to fish identified here as *G. rufa*, differing only in having a naked breast (chest or anterior belly) in some fish (or with embedded scales in one population, see Esmaeili *et al*. (2016)). Berg (1949) described *Garra rufa gymnothorax* from the Iranian Karun and Dez River drainages, distinguishing *G. r. gymnothorax* from *G. r. rufa* by its naked breast (versus scaled). Alexander Naseka (Dolsko) examined syntypes (ZISP 13214, 13215) of this nominal species for Esmaeili *et al*. (2016), and these fishes indeed have a naked breast as described by Berg (1949). My examination of material identified as *G. rufa* (*q.v.* herein) showed that breast scales are usually overlain by skin and mucus and difficult to see. Variation in extent of scales on the anterior ventral surface makes separation of *G. gymnothorax* and *G. rufa* difficult in absence of other unequivocal characters. Few fish from Iran have scales extending to the isthmus and most fish have scalation terminating at varying levels between the bases of the pectoral fins. This may vary with development (size and age), individual variation, locality and habitat, without any taxonomic significance but this has not been investigated in detail. The paper by Esmaeili *et al*. (2016) indicating syntopic occurrence of *G. gymnothorax* and *G. rufa* in Iran on molecular data did not examine material of *G. rufa* from the type locality (Aleppo, Syria) or nearby. I refer most fish here from Iran to *G. rufa* (*q.v.*) while recognising some may be cryptic or misidentified *G. gymnothorax*, only clearly identifiable by molecular analyses at present. J. Freyhof (pers. comm., 23 April 2016; and see Sayyadzadeh *et al*. (2015)) has noted that there are populations of *G. rufa* in Turkey that have a naked breast and populations of *G. gymnothorax* with breast scales so this character is not sufficient.

**Key characters.** This species is distinguished from all other species of *Garra* in the

Tigris River and Persis basins according to Esmaeili *et al*. (2016) by a combination of characters, none of them unique. The breast is naked or with embedded scales in one population (versus covered by scales in *G. rufa*), the belly and predorsal mid-line are covered by scales (versus naked in *G. mondica*), the eye is placed in the posterior half of the head (versus slightly in the anterior half in *G. amirhosseini*), usually 8 dorsal fin branched rays (versus 7 in *G. amirhosseini* and *G. mondica*), a fully developed mental disc (versus weakly-developed in *G. rossica* and *G. variabilis*), normal pigmentation and eyes (versus little pigmentation and no eyes in cave fish species), modally 17 caudal fin branched rays (versus 16 in *G. persica*), and two pairs of barbels (versus one pair in *G. variabilis* or none in *G. roseae*). Zamani-Faradonbe *et al*. (2021) in their key to *Garra* from the Tigris River basin and coastal rivers did not separate *G. gymnothorax* and *G. rufa* on external morphological characters.

**Morphology.** The following description is taken from Esmaeili *et al*. (2016) but note reservations on distinction of this species from *G. rufa* above. The body is elongated, moderately compressed laterally, and more compressed in the region of the caudal peduncle. The dorsal head profile rises gently, flat or slightly convex, and more or less continuous with the dorsal body profile to the nape or to about the middle between the nape and the dorsal fin origin. The ventral profile is more or less straight to the anal fin origin. The head is moderately large and depressed, with a slightly convex or flat interorbital distance. Head depth at the nape is less than head length. Head width at the nape is greater or about equal to the depth at the nape. The eye is placed dorso-laterally partly in the posterior half of the head (see illustrations). Barbels are in two pairs, the rostral barbel antero-laterally located, shorter or about equal to the eye diameter, and the maxillary barbel at the corner of the mouth, shorter than the rostral barbel. There is a well-developed disc with free lateral and posterior margins. The disc is heavily papillate with batteries of fleshy papillae arrayed around the periphery of the whole disc. The disc is elliptical, shorter than wide, and narrower than the head width through the base of the maxillary barbels. The rostral cap is well-developed, fimbriate, and papillate on the ventral surface. An upper lip is present as a thin band of papillae arranged in two ridges. The upper jaw is almost or completely, covered by the rostral cap. The dorsal fin distal margin is concave, the origin closer to the snout tip than to the caudal fin base, and anterior to the vertical from the pelvic fin origin. The first branched dorsal fin ray is the longest, the tip of the last branched ray reaching back to a vertical from the anus. The caudal fin is forked with lobe tips pointed. The anal fin is short, the first branched ray is the longest, the distal margin is straight or slightly concave, and the origin is closer to the pelvic fin origin than to the caudal fin base. The pelvic fin reaches back to the anus, the origin closer to the anal fin origin than to the pectoral fin origin and below the second or third branched dorsal fin ray. The pectoral fin reaches back to a point 3-4 scales anterior to the pelvic fin origin, and is shorter or slightly equal to the head length.

Dorsal fin with 3 unbranched and 7(5) or 8(38) branched rays, anal fin with 3 unbranched and 5 branched rays, pectoral fin with 12-17 branched rays, and pelvic fin with 7-8 branched rays. Scales on the flank are regularly arranged. The lateral line is complete with 32(6), 33(7), 34(8), 35(3), 36(3) or 37(8) scales (and to 38 after Jouladeh-Roudbar *et al*. (2020)), with 2-3 on the caudal fin base. Transverse scale rows above lateral line number 3-4, between the lateral line and the pelvic fin origin 2-3, scales around the caudal peduncle are 12-13, and usually, there are 10-12 scales on the predorsal midline. The chest is naked and, in one population, with hidden scales. The belly is covered by scales. There is one short axillary scale at the pelvic fin base in some individuals, and 4-7, usually 5, scales between the posteriormost

pelvic fin base and the anus. The anus is 3-4 scales in front of the anal fin origin. Total gill rakers 17(4), 18(11), 19(10), 20(8), 21(3), 22(1) or 23(4). Total vertebrae 33-37 (Jouladeh-Roudbar *et al*., 2020).

**Sexual dimorphism.** None reported.

**Colour.** Colouration resembles that in *G. rufa* with an overall brown colouration with some flank scales darkly pigmented and others lighter giving a mottled appearance, and lighter on the belly. Dorsal and caudal fin rays pigmented with membranes almost hyaline, anal and paired rays much lighter. The base of dorsal fin branched rays 3-5 has dark spots.

**Size.** Reaches 88.6 mm standard length.

**Distribution.** This species is reported from the Tigris River basin in Iran and neighbouring Iraq. In Iran, Berg (1949) recorded this species from Kulihan in the Karun River basin (or Kuhlihan, Kulikhan, Kulichan) probably at 32°00'N, 49°05'E after Roselaar and Aliabadian (2007)) between Shushtar and Qaleh-ye Tol elsewhere in Berg (1949)), Malamir (= Izeh in the Khersan River drainage in the upper Karun River basin), and at Dezful on the Dez River. Sayyadzadeh *et al*. (2015) listed the Beshar River northeast of Yasuj (upper Khersan River basin) and the Sangan Stream at Sangan (Khersan River basin). Esmaeili *et al*. (2016) cited the Helayjan River at Izeh, the Balarud at Andimeshk (Dez River basin), and the Beshar River at Yasuj. Hashemzadeh Segherloo *et al*. (2018) recorded it from the Dez, Karkheh and Karun river basins. Beshar, Helayjan and Balarud River fish identities were based on DNA work, as well as morphology, although the identity was given as *G. cf. gymnothorax* (Esmaeili *et al*., 2016). Fatemi *et al*. (2019) reported it from the Marun (Tigris River basin) and Zohreh (Persis basin) rivers. Zamani-Faradonbe *et al*. (2021) recorded fish from the Karkheh and Karun River basins and from the Bala or Balarud, Beshar, Gamasiab, Gharesoo (= Qareh Su), Kashkan and Khersan rivers based on DNA data.

**Zoogeography.** See under the genus.

**Habitat.** This species is found in rivers and streams.

Habitat of *Garra gymnothorax*, Khuzestan, Helayjan River, Hamid Reza Esmaeili.

**Age and growth.** Zamani-Faradonbe *et al*. (2018) found a *b* value of 3.11 for 45 fish, 2.8-9.5 cm total length, from Iran.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

**Economic importance.** None.

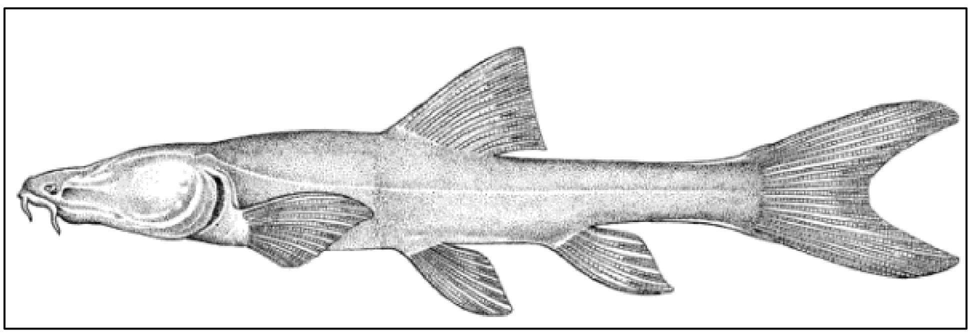
**Experimental studies.** None.

**Conservation.** The full range of this species has yet to be determined but it is unlikely to be under any immediate threat. Jouladeh-Roudbar *et al*. (2020) listed it as Least Concern as it is widespread, ubiquitous and occurs in high population sizes.

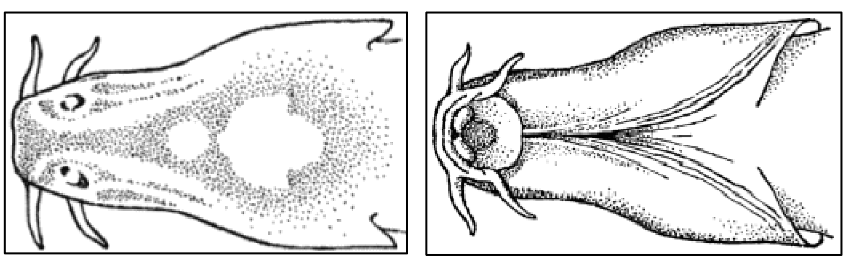
**Sources.** Type material:- *Garra rufa gymnothorax* (ZISP 13214).

Iranian material:- See Esmaeili *et al*. (2016).

## ***Garra lorestanensis***
Mousavi-Sabet and Eagderi, 2016



*Garra lorestanensis*
Charles H. Douglas @ Canadian Museum of Nature.

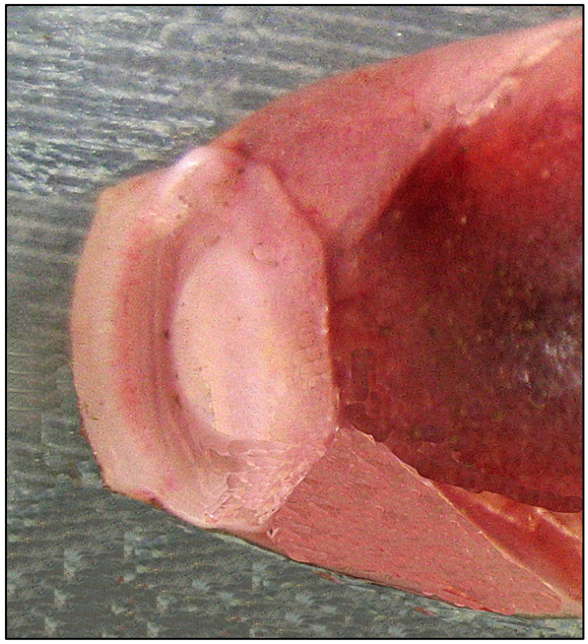


*Garra lorestanensis*, dorsal and ventral heads
Charles H. Douglas @ Canadian Museum of Nature.

*Garra lorestanensis*, Lorestan, Loven Cave, Mr. Amiri via H. Barani Beiranvand.

*Garra lorestanensis*, dorsal view, Lorestan, Loven Cave, Mr. Amiri via H. Barani Beiranvand.

*Garra lorestanensis*, ventral view, Lorestan, Loven Cave, Mr. Amiri via H. Barani Beiranvand.



*Garra lorestanensis*, disc, Lorestan, Loven Cave,
Mr. Amiri via H. Barani Beiranvand.

*Garra lorestanensis*, variation in disc development,
modified after Hashemzadeh Segherloo *et al*. (2018).

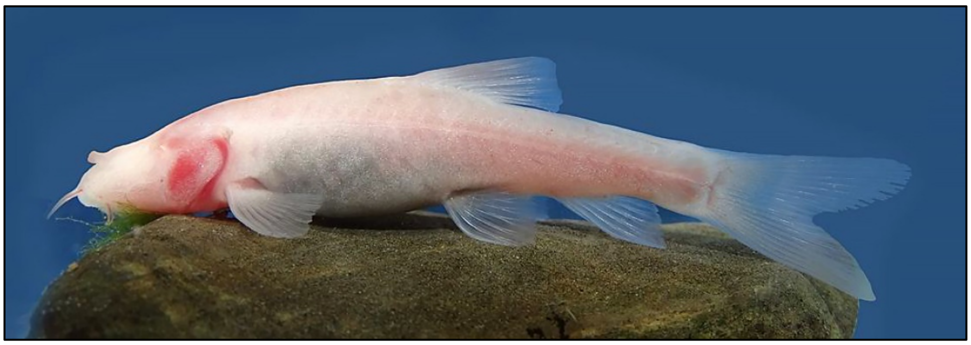
**Common names.** Mahi kor (or kur) lorestani (= Lorestan blind fish).

[Blind cave garra, Lorestan blind fish].

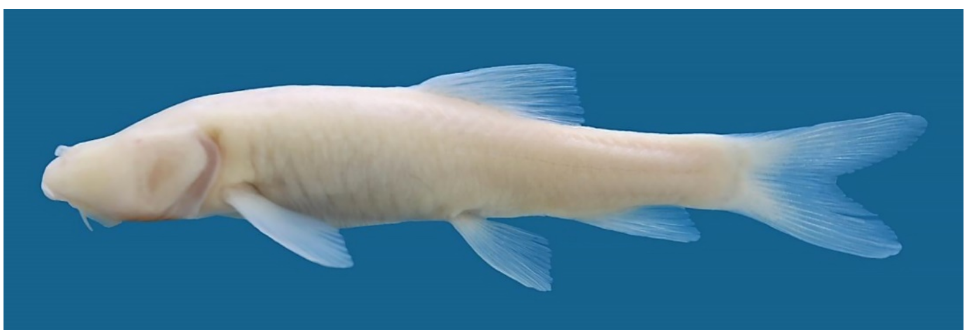
**Systematics.** Sargeran *et al*. (2008) reported on two forms of the Iranian cave fish, one with, and one without, a mental or chin disc, these having significant differences in some morphometric and meristic characters. Hashemzadeh Segherloo *et al*. (2012) found these two forms had a mean genetic distance, based on DNA evidence, higher than intraspecific divergence. They thought the two forms could represent separate species, with an affinity to the genus *Garra*. One form lacks a mental disc and has a reduced intestine, perhaps signs of evolutionary reduction in a subterranean habitat without much water flow (and hence no need of a disc) and differing feeding habits (reduced intestine). Hashemzadeh Segherloo *et al*.

(2014) referred to one of the two forms as an undescribed species. Genetic evidence confirms two species are present (Hashemzadeh-Segherloo *et al*., 2012; Farashi *et al*., 2014; Sayyadzadeh *et al*., 2015; Hashemzadeh Segherloo *et al*., 2018). Further discussion is under *G. typhlops*.

Mousavi-Sabet and Eagderi (2016) described the form with a mental disc as new. The holotype is 55.0 mm standard length and is in the Vatandoust and Mousavi-Sabet Fish Collection, Tehran (VMFC GL-H) with paratypes VMFC GL-P1-3, 3, 27.2-58.0 mm standard length and in the Collection of the Ichthyology Museum, Department of Fisheries Sciences, Faculty of Natural Resources, University of Guilan (GUIC) under GUIC GL-P2, 2, 31.6-45.1 mm standard length.



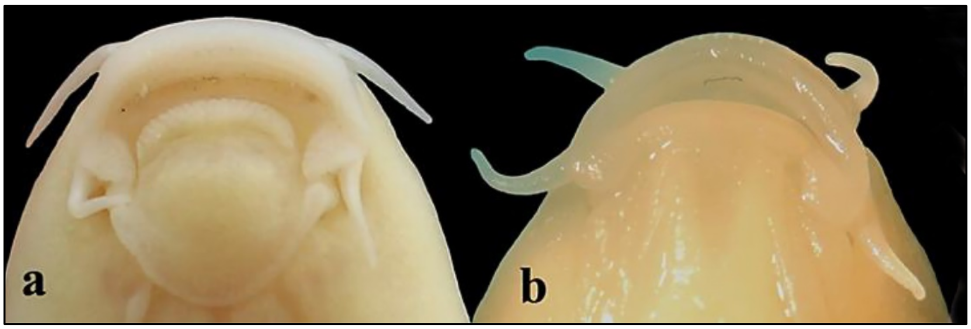
*Garra lorestanensis*, holotype, Hamed Mousavi-Sabet.



*Garra lorestanensis*, holotype, Hamed Mousavi-Sabet.


*Garra lorestanensis*, holotype, head views, a, lateral, b, dorsal, c, ventral, Hamed Mousavi-Sabet.

**Key characters.** The lack of eyes and pigment separates this taxon from other *Garra* species, the presence of a mental disc from *G. typhlops*, and an elliptical, rather than round, disc and presence of 28-35 lateral line pores from *G. tashanensis*. This species is also distinguished from *G. typhlops* by a longer intestine, a single or bipartite swimbladder (versus bipartite), reduced preorbital bones enclosing the infraorbital canal (versus absent), commonly 35 vertebrae (versus commonly 34), and other osteological characters. Other characters are given in the *G. tashanensis* account.




Ventral heads of a, *Garra lorestanensis* (holotype, 55.0 mm standard length)
and b, *Garra typhlops* VMFC GT01, 41.0 mm standard length), Hamed Mousavi-Sabet.

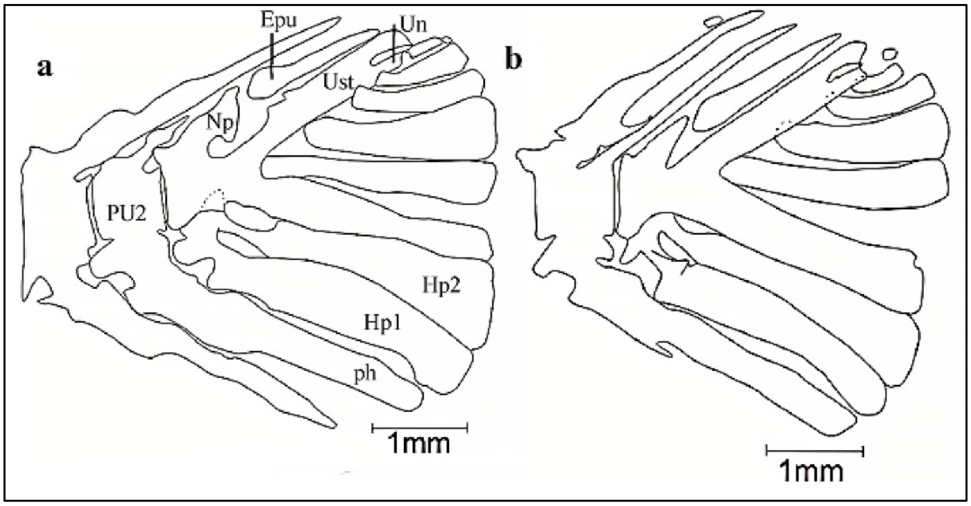
**Morphology.** This is a relatively stout species with a wide head, a moderately compressed body laterally, and more compressed posteriorly especially in the caudal peduncle region. The body is deepest at, or slightly in front of, the dorsal fin base, the depth decreasing towards the caudal fin base. The greatest body width is at, or slightly behind, the pectoral fin base, and the body is almost equally wide until the dorsal fin origin. The head is relatively large, and deeply depressed. The dorsal head profile rises gently from the tip of the snout, slightly convex and sharply continuous with the dorsal body profile from about the middle between the tip of the snout and the nape to about the middle between the nape and the dorsal fin origin. The ventral profile is slightly concave in the pectoral-pelvic contour, and more or less straight from the pelvic to the anal fin origin. The caudal peduncle is relatively shallow (caudal peduncle depth 9.5-11.5% standard length). The caudal peduncle length is 1.4-1.8 times longer than its depth. The snout is roundish with a shallow transverse groove between the transverse lobe and the proboscis in larger specimens, and no obvious groove in small individuals. The proboscis is not (commonly in small individuals) or only slightly (in larger specimens) elevated from the depressed rostral surface. The anterior arm of the depressed rostral surface does not reach to the base of the rostral barbel, separating the transverse lobe from the lateral surface. Commonly, there is no obvious groove between the transverse lobe and the lateral surface. The mouth has two pairs of barbels, the rostral barbel antero-laterally and the maxillary barbel at the corner of the mouth, shorter than the rostral barbel. The rostral cap is poorly developed, fimbriate, and papillate on the ventral surface. The upper lip is present and the upper jaw is almost covered by the rostral cap. The disc is elliptical, longer than wide, and narrower than the head width through the roots of the maxillary barbel. There are papillae on the antero-median fold of the disc, a well-developed groove between the antero-median fold and the central callous pad is narrow, and deep, scattered small-sized papillae are present on the latero-posterior flap. The surface of the central callous pad has sparsely arranged small papillae. The anterior dorsal fin origin is located mid-dorsum, or slightly posterior. The margin of the dorsal and anal fins is straight or slightly concave. The caudal fin is distinctly forked

with the lobe tips pointed. The pelvic fin origin is behind a vertical from the dorsal fin origin, about vertical from the mid-dorsal fin base. The pectoral fin reaches approximately 55-60% of the distance from the pectoral fin origin to the pelvic fin origin.

*Garra lorestanensis*, holotype, ventral view showing coiled gut, Hamed Mousavi-Sabet.

Dorsal fin with 3 unbranched and 7-8 branched rays, anal fin with 5 branched rays, pectoral fin branched rays 12-14, and pelvic fin branched rays 6-7. The body is naked or scaleless. Total gill rakers number 10-12. Pharyngeal teeth are 3,4,5-5,4,3. The gut is elongate and coiled as in in other *Garra* species. Total vertebrae number 34-35 (Jouladeh-Roudbar *et al*., 2020).

Jalili and Eagderi (2014c) gave details of osteological differences with related *Garra rufa* including shape of skull bones, and absence of the lachrymal, presumably related to reduction in the orbit as this species is eyeless, and changes in the lower jaw, suspensorium, hyoid arch and reduction of the ventral masticatory plate, presumably related to feeding conditions in the cave habitat. The fish were identified as *Iranocypris typhlops* but the fish were *G. lorestanensis* because of the presence of a disc. Esmaeilzadegan (2013) also described the osteology in detail of "*Iranocypris typhlops*" in comparison with *G. rufa* but this too may include *G. lorestanensis* or be restricted to one or the other cave species. Mousavi-Sabet and Eagderi (2016) also gave comparative osteological features distinguishing the two species in the Loven Cave, including reduced preorbital bones that enclose the infraorbital canal in *G. lorestanensis* (versus absent in *G. typhlops*), the posterior pharyngeal process of the basioccipital is broad and directed horizontally with a vertical ridge on its ventral face (versus directed vertically with lateral ridges), commonly 35 vertebra (versus commonly 34 vertebrae), a wider haemal spine of the fourth fused vertebra of the Weberian apparatus (versus narrow), and a small PU2 with a short neural spine in the caudal skeleton (versus PU2 well-developed with a long neural spine).



Caudal skeleton of a, *Garra lorestanensis*, 74.0 mm standard length, VMFC GL-NT1 and b, *Garra typhlops*, 55.8 mm standard length, VMFC GT08 (Epu = epural, Hp = hypurals, Np = neural process, Ns = neural spine, Ph = parhypural, PU2 = second preural centra, Un = uroneural, and Ust = pleurostyle), Hamed Mousavi-Sabet.

**Sexual dimorphism.** Male fish have scattered, small tubercles on the lateral snout reaching back to the posterior nostril in large fish. There are no obvious head tubercles in small individuals.

**Colour.** The body is pinkish to red from blood visible through the skin. The gill filaments are suffused with blood and this area of the body is bright red on that account. The brain appears as a dark spot. All fins are hyaline. Preserved fish are yellowish-white.

**Size.** Reaches 74.0 mm standard length.

**Distribution.** Originally restricted to the Loven Cave locality described in more detail under *G. typhlops*, this species may be widely distributed in a freshwater aquifer in the Zagros Mountains. Mahjoorazad and Coad (2009) reported a cave fish from the Simareh River basin (now buried under a dam - see under *G. typhlops*) which could be this species, *G. typhlops* or both species, and Vatandoust *et al*. (2019) found cave fishes at a third locality, Tuveh Spring 31 km southeast of the Loven Cave in the Dez River drainage, identified as both species based on molecular and morphological data. Local informants reported numerous other spring localities (Jouladeh-Roudbar *et al*., 2020).

**Zoogeography.** See under *G. typhlops* and under the genus.

**Habitat.** See under *G. typhlops*. The Tuveh Spring flows mainly between autumn and spring, depending on local rainfall. More than 300 juvenile fish (*G. lorestanensis* and *G. typhlops*) were carried out of the cave system and trapped in small ponds on the river bed where they die from desiccation or are eaten by predators such as birds (Jouladeh-Roudbar *et al*., 2020).

a 

Lorestan, Loven Cave habitat, Asghar Mobaraki.

Lorestan, Loven Cave habitat with higher water level, Hamed Mousavi-Sabet.

**Age and growth.** See under *G. typhlops* where the two species are conflated.

**Food.** See under *G. typhlops* where the two species are conflated. Fish with a disc can attach to and graze on the substrate; a significantly longer intestine in such fish may be indicative of a detrital feeding habit (Sargeran *et al*., 2008).

**Reproduction.** See under *G. typhlops* where the two species are conflated. Jouladeh-Roudbar *et al*. (2020) suggested early March as the spawning season based on the appearance of Tuveh Spring juveniles.

**Parasites and predators.** None reported.

**Economic importance.** See under *G. typhlops*.

**Experimental studies.** None.

**Conservation.** See also under *G. typhlops*. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern because of the numerous reports cited above while the IUCN Red List (2019 version) gave it as Not Evaluated.

**Sources.** Mousavi-Sabet and Eagderi (2016).

Iranian material:- CMNFI 2007-0124, 2, 27.0-31.6 mm standard length, type locality as above; CMNFI 2008-0176, 1, 31.2 mm standard length, type locality as above.

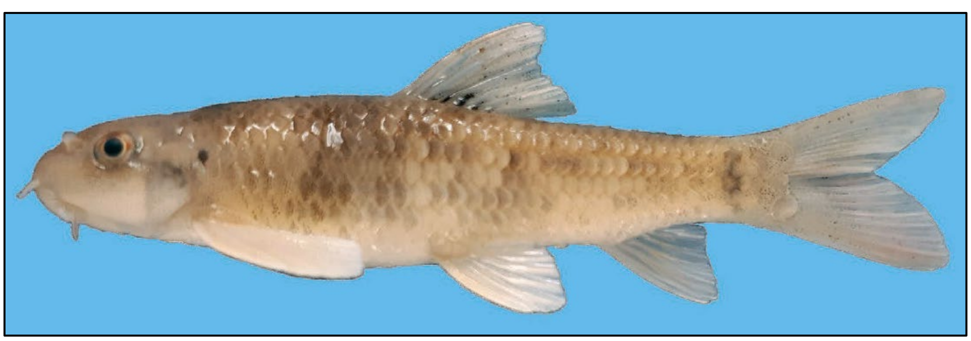
### *Garra meymehensis*

Zamani-Faradonbe, Keivany, Dorafshan and Zhang, 2021

*Garra meymehensis*, 38.0 mm standard length, CMNFI 1979-0367, Khuzestan, Meymeh River 11 km north of Dehloran (32°44'30"N, 47º09'30"E), Marie-Hélène Hubert @ Canadian Museum of Nature.

**Common names**. None.

**Systematics.** The holotype is under IUT-IM (Isfahan University of Technology Ichthyology Museum) M43, 49.0 mm standard length, Iran, Ilam Prov., Meymeh River at km 16 on road from Dehloran to Mehran, 32°44'33"N, 47°9'23"E, and paratypes are under IUT-IM 13981019-01-01, 57, 33.7-71.4 mm standard length, collected with the holotype. The species is named after the Meymeh River.



*Garra meymehensis*, holotype, IUT-IM M43, Yazdan Keivany.

**Key characters.** *Garra meymehensis* is distinguished from other species of *Garra* in the Tigris River and Persis basins by a combination of characters, none of them unique to the species. It is normally pigmented, has two pairs of barbels, free lateral and posterior margins to

the mental disc, modally 7 branched dorsal fin rays, the predorsal midline is usually covered by non-embedded exposed scales, the breast is covered by large embedded scales and scales on belly are not embedded in the skin, by the mitochondrial COI barcode region, and distribution in the Meymeh River of the Tigris River basin.

**Morphology.** The body is small-sized, elongated and rounded with a relatively deep caudal peduncle. Caudal peduncle length is 0.8-1.5 times longer than its depth. The dorsal head profile rises gently from the tip of the snout to the nape, and the dorsal profile of the back is slightly convex from the nape to the dorsal fin origin. The ventral profile is more or less straight between the pectoral fin insertion and the anal fin origin. The body is deepest at, or slightly in front of, the dorsal fin base and the body depth decreases towards the caudal fin base. The greatest body width is at, or slightly behind, the pectoral fin base. The body is almost equally wide from the pectoral fin base to the dorsal fin origin. The head is moderately large (23.3-28.7% standard length) and slightly depressed (57-73% head length). The interorbital space is slightly convex or flat, the height at the nape less than head length. The head length is 0.8-1.4 times in body depth. The snout is rounded, its length 0.6-1.5 times in the postorbital length. There is no obvious tubercle on the transverse lobe and it is demarcated posteriorly by a shallow transverse groove in some specimens. The transverse lobe is moderately separated from the lateral surface in large specimens. The anterior arm of the depressed rostral surface does not reach to the base of the rostral barbel. There is no groove between the transverse lobe and the lateral surface in some individuals. The eye is relatively large, positioned at mid-head, its diameter 0.25-0.5 times in head depth and 0.25-0.46 times in interorbital width. There are two pairs of thin barbels, the maxillary barbel at the corner of the mouth shorter (0.7-0.8 times) than the rostral barbel, the rostral barbel anterolaterally located and shorter (0.7-0.9 times) than the eye diameter. The rostral cap is well-developed, fimbriate, papillate on its ventral surface. The upper lip presents as a thin band of papillae arranged in one or two ridges. The upper jaw is almost or completely covered by the rostral cap. The disc is almost oval in shape, longer than wide, and narrower than head width through the base of the maxillary barbels. Papillae on the anterior fold are equal-sized and regularly arranged. There is a narrow and deep groove between the anteromedial fold and the central callous pad (shallow in some individuals). There are scattered and small-sized papillae on the latero-posterior flap. The surface of the central callous pad is without, or with, sparsely arranged small papillae. The last unbranched dorsal fin ray is shorter than the head length, the distal fin margin is slightly concave, the fin origin is closer to the snout tip than to the caudal fin base, the fin origin is well anterior to the level of the pelvic fin origin, the first branched ray is the longest, and the tip of the last branched ray reaches a vertical to, or slightly in front of, the anus when folded down. The caudal fin is distinctly forked with lobes pointed to rounded, the lower lobe the largest. The first branched anal fin ray is the longest, the fin distal margin is straight or slightly concave, the fin origin is closer to the caudal fin base than to the pelvic fin insertion in most specimens, and the fin extends back to the caudal fin anterior rays. The pelvic fin tip does not reach to, or almost reaches, the anus or the anterior margin of the anal fin base. The insertion of the pelvic fin is closer to the anal fin origin than to the pectoral fin insertion. The tip of the pectoral fin reaches approximately a point 3-4 scales anterior to the pelvic fin insertion and its length is shorter than head length. The anus is 2(4) or 3(16) scales distant from the anal fin origin.

Meristic values from Zamani-Faradonbe *et al.* (2021) and some material below are:- dorsal fin with 2-3 unbranched and 7(56) or 8(4) branched rays, anal fin unbranched rays 2, branched rays 5, pectoral fin branched rays 10(3), 11(45), 12(3) or 13(9), and pelvic fin

branched rays 6(3), 7(56), 8(-) or 9(1). Lateral line complete, with 33(12), 34(29), 35(15), 36(3) or 37(1) scales, and 2-3 scales on the caudal fin base. Transverse scale rows above the lateral line 3(2), 4(52) or 5(6), scale rows between the lateral line and pelvic fin insertion 3(17) or 4(43), scale rows between the lateral line and anal fin origin 3(34), 4(25) or 5(1), and circumpeduncular scale rows 11(1), 12(1), 13(1), 14(12), 15(27) or 16(18). There are 11 non-embedded exposed scales along the predorsal midline of 48 specimens and 10 specimens bear slightly or deeply-embedded scales on the predorsal midline. The chest is covered by embedded scales. Scales on the belly have free margins, exposed, not embedded in the skin. The chest and belly are scaleless in 8 out of 58 specimens, and there are 6(14) or 7(6) scales between the tip of the pelvic fin and the anus. Scale characters are similar to those in *G. tiam* but with few to no radii in the lateral fields in the small fish available. Total gill rakers 16(2), 17(4), 18(6), 19(4), 20(-) or 21(1), short, reaching the adjacent raker or just past it when appressed.  Pharyngeal teeth are similar to those in *G. tiam*. Total vertebrae 34.

**Sexual dimorphism.** Small- or medium-sized tubercles are sparsely set on the proboscis, larger on its anterior margin. Small- to medium-sized tubercles are scattered through the lateral and dorsal surface of the snout reaching the posterior nostril in most specimens, or the anterior orbital margin in a few. The depressed rostral surface always lacks tubercles.

**Colour.** Live fish have a bright silvery to pale green background colour. Fins are mostly hyaline, paired fins being golden yellow with black dots. The head is grey to green. The iris is silvery orange with a dark brown spot at the upper portion. Scales on the flanks are silvery-green and dark grey, whitish or pale grey on the ventral part of the flank and belly. The rostral barbel has small black dots. There is a black blotch at the anteriormost lateral line, absent in some or pale blue. The dorsal fin has a black bar on the base of rays 2-7 and the adjacent membranes, and some black or brown blotches on the middle and distal dorsal fin membranes. Preserved fish have the dorsal surface of the head, back and flank pale brown. Single or patches of dark-brown scales are on the flanks. The ventral surface of the head, mouth, chest and abdomen are whitish-yellow. A large, 2-3 scales wide, black bar is on the distal portion of the caudal peduncle, very conspicuous in most specimens, faded in a few. The pectoral, pelvic and anal fins are light grey to yellow. There are some black to dark-brown blotches are on caudal fin membranes.

**Size.** Reaches 71.4 mm standard length.

**Distribution.** This species is found in the Tigris River basin in the perennial Meymeh River of Iran. In Iraq, this river is known as the Nahre-Al-Tayeb and flows into the Tigris River near Al-Amarah.

**Zoogeography.** Zamani-Faradonbe *et al*. (2021) using the mitochondrial COI barcode region recovered 12 lineages including a clade for specimens of *Garra* from Meymeh River, and a clade for specimens of *Garra* from Abshur or Ab-e Shur River (*G. tiam*, see below). These two together with *G. gymnothorax* were grouped in a more inclusive clade in the Tigris River basin. The phylogenetic tree recovered the species of the *G. rufa* species-group split in three main clades: Clade I: *G. gymnothorax*, *G. lorestanensis*, *G. meymehensis*, *G. tiam* and *G. typhlops*; Clade II: *G. amirhosseini*, *G. elegans* (of Iraq), *G. mondica*, *G. persica*, *G. rufa* and *G. widdowsoni* (of Iraq); and Clade III: *G. tashanensis*.

**Habitat.** This species is found in streams and rivers. Collection data included a temperature of 14ºC, pH 6.0, conductivity 1.65-6.0 mS, river width 3.0-20 m, medium current, water depth 35-100 cm, clear water and mud and pebble bottoms, encrusting vegetation, and a grassy shore.

**Age and growth.** Unknown.
**Food.** Unknown.
**Reproduction.** Unknown.
**Parasites and predators.** None reported.
**Economic importance.** None.
**Experimental studies.** None.
**Conservation.** The Meymeh River is polluted and this may affect populations of this species (Cheraghi *et al*., 2007).
**Sources.** Zamani-Faradonbe *et al*. (2021).
Iranian material:- CMNFI 1979-0366, 2, 22.7-29.2 mm standard length, Khuzestan, stream 17 km west of Dehloran (32º45'30"N, 47º05'30"E); CMNFI 1979-0367, 1, 38.0 mm standard length, Khuzestan, Meymeh River 11 km north of Dehloran (32º44'30"N, 47º09'30"E).

## *Garra mondica*
Sayyadzadeh, Esmaeili and Freyhof, 2015

*Garra mondica*, paratype, 62.9 mm standard length, ZM-CBSU H1030 (*sic*, presumably 1033), Hamid Reza Esmaeili.

**Common names.** Gelkhorak Mond and gel cheragh Mond (Jouladeh-Roudbar *et al*., 2020).
[Mond garra].
**Systematics.** The holotype is 66.0 mm standard length (65.9 mm in Table 3) and is from Fars, Konar Siyah spring at Firuzabd (*sic*, Firuzabad), 28º43'40"N, 52º25'20"E, under ZM-CBSU H1032 (Zoological Museum of Shiraz University, Collection of Biology Department). Paratypes are under ZM-CBSU H1033, 8, 39-64 mm standard length, same locality as the holotype, ZM-CBSU K1080, 7, 41-58 mm standard length, same locality as the holotype, ZM-CBSU B242, 1, 48 mm standard length, ZM-CBSU B250, 1, 53 mm standard length and ZM-CBSU B255, 1, 49 mm standard length, Fars, Tang-e-Mohr spring at Lamerd, 27º31'36"N, 52º51'47"E.
**Key characters.** This species is distinguished from neighbouring *Garra rufa* populations in the Mond River basin, and from other species in rivers flowing into the Persian Gulf south of the Tigris River basin, by having a naked breast, anterior belly and predorsal midline (or midline with a few, usually embedded scales) (versus scaled), by usually 7 dorsal fin branched rays (versus 8), and by DNA data. It is distinguished from *G. persica* additionally by having 17 branched caudal fin rays (versus usually 16) and 18-23 total gill rakers (versus 11-15), from *G. variabilis* by having a fully developed mental disc (versus reduced) and two

pairs of barbels (versus one), and from cave fish *Garra* species by having well-developed eyes (versus none) and a brown or grey colour (versus no pigment).

**Morphology.** The body is elongated, moderately compressed laterally, and more compressed in the region of the caudal peduncle. The dorsal head profile rises gently, slightly convex, and more or less continuous with the dorsal body profile to the nape or about the middle between the nape and the dorsal fin origin. The ventral profile is more or less straight to the anal fin origin. The head is moderately large and depressed, with a slightly convex or flat interorbital space, the depth at the nape is less than head length, and the width at the nape is greater or about equal to the depth at the nape. The snout is roundish, the transverse lobe has its tubercles demarcated posteriorly by a shallow transverse groove in some individuals, and there is no transverse groove in others. The proboscis is not, or only slightly, elevated from the depressed rostral surface. The dorsal fin origin is well in advance of the level of the pelvic fin origin and the fin margin is concave. The depressed dorsal fin does not reach back to a level with the anal fin origin. The caudal fin is moderately forked and has rounded tips. The anal fin margin is rounded and the fin reaches back to the procurrent rays of the caudal fin. The pelvic fin margin is rounded and the fin just reaches back to the anal fin origin. The pectoral fin margin is rounded and the fin falls well short of the origin of the pelvic fin. The above is mostly after Esmaeili *et al*. (2016) and the illustration.

Dorsal fin with 3 unbranched and 7(28) or 8(12) branched rays, anal fin with 3 unbranched rays and 5 branched rays, pectoral fin branched rays 12-14, and pelvic fin branched rays 7-8. Lateral line scales 28(1), 29(2), 30(6), 31(9) or 32(8) (or to 34 after Jouladeh-Roudbar *et al*. (2020)). Scales above lateral line 3-4, scales below lateral line to both pelvic and anal fin origins 3. Scales around the caudal peduncle 13-14. The anus is 2-3 scales in front of the anal fin origin. Predorsal midline scales absent (20 fish), or 2-4 scales present in front of dorsal fin (7) or with a few deeply, embedded scales on midline (9). Some fish have embedded scales between the posterior tip of the pectoral fin and the pelvic fin base. A pelvic axillary scale is present. Usually there are 5 (4-6) scales between the posteriormost pelvic fin base and the anus, embedded in some individuals. Total vertebrae number 33-36 (Jouladeh-Roudbar *et al*., 2020).

**Sexual dimorphism.** The transverse lobe of the snout has 11-21 tubercles demarcated posteriorly by a groove in some fish. The proboscis is covered with small or medium-sized tubercles, largest on the anterior margin of the proboscis. The lateral snout is covered by small to medium-sized tubercles reaching to the anterior eye in some fish or to the posterior nostril in others. The depressed rostral surface always lacks tubercles.

**Colour.** Live fish have a grey head and flank scales are dark grey with individual or groups of pale grey scales forming a mottled pattern. The ventral flank and belly are whitish or pale grey. The iris is silvery-orange. Fins are hyaline with black spots or lines of pigment on the rays. There is a pale blue dot at the anteriormost lateral line reaching down to the upper pectoral fin base in some fish. There is a faint, irregularly-shaped midlateral stripe in a few fish. In preserved fish, the head, back and flank are dark or pale brown. The flank has single or groups of dark brown scales. A very faint, irregular, dark brown, midlateral stripe is restricted to the posterior flank, absent in some fish, and usually interrupted. The mouth, breast and abdomen are yellowish-white. The posteriormost caudal peduncle bears a wide black or dark brown bar, faded in some or bold and 2-3 scales wide in others. The bar reaches the dorsal midline in most fish, not reaching the ventral midline. There is a small black blotch at the anteriormost lateral line. Lateral line pores are cream whitish. Fins are hyaline with black

pigmentation spots or lines on the rays, or rays are partly dusky grey or black. The base of the last 3-6 dorsal fin branched rays has a black spot or is black in fish larger than 40 mm standard length, hyaline in others.

**Size.** Reaches 65.9 mm standard length.

**Distribution.** This species is found in the Persis basin in two small springs, Konar Siyah and Tang-e Mohr, in the Daralmizan and Firouzabad rivers of the Mond River basin in Fars and the Shur River of Hormozgan (Sayyadzadeh et al., 2015; Esmaeili *et al*., 2016; Gholamifard, 2017; Zamani-Faradonbe and Keivany, 2021a).

**Zoogeography.** This species is related to an undescribed taxon from the neighbouring Kul River drainage which may in fact be introgressed *G. rufa* or *G. persica* with *G. mondica*. More generally, *G. mondica* is related to *Garra rufa* populations of the Tigris-Euphrates and adjacent basins in southern Iran. However, Bayçelebi *et al*. (2018) stated that *Garra turcica* Karaman, 1971 of southern Anatolia has this species as one of its closest relatives (along with *G. elegans* (Günther, 1868) of the Tigris River basin and *G. amirhosseini*). See also under the genus.

**Habitat.** This species is found in spring, stream and river habitats. A habitat photograph shows rapid water flow and a bedrock and boulder stream bed. There is little riparian shade.

Habitat of *Garra mondica*, Fars, Konar Siyah Spring, Hamid Reza Esmaeili.

**Age and growth.** Zamani-Faradonbe *et al*. (2018) found a *b* value of 2.87 for 14 fish, 5.0-6.8 cm total length, from Iran.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

**Economic importance.** None.

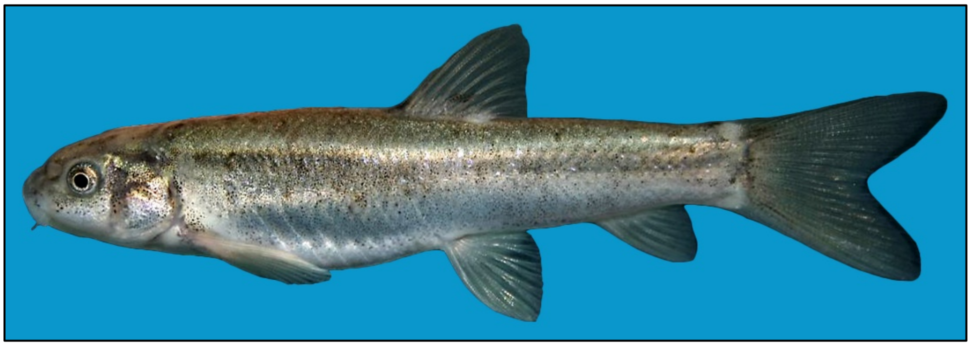
**Experimental studies.** None.

**Conservation.** The species is known from only two small springs and one river locality and so is susceptible to habitat loss by drought or water diversion, loss from pollution or loss from exotic predators. Jouladeh-Roudbar *et al*. (2020) listed it as Vulnerable in part on the

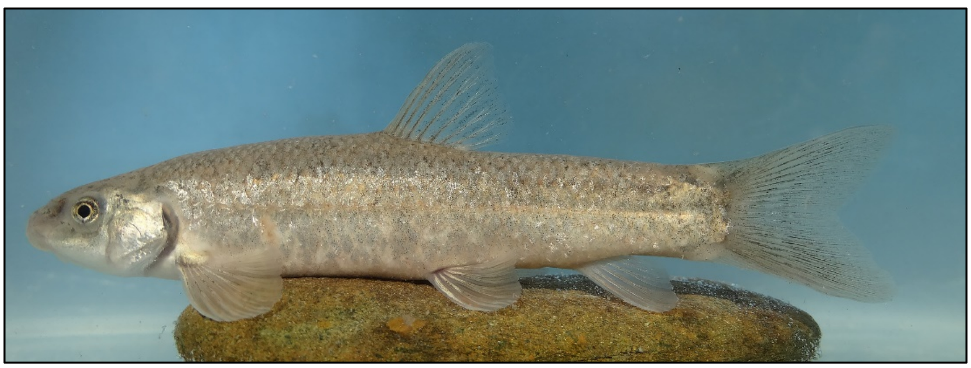
above basis and on degradation from agriculture.

**Sources.** Sayyadzadeh *et al*. (2015).

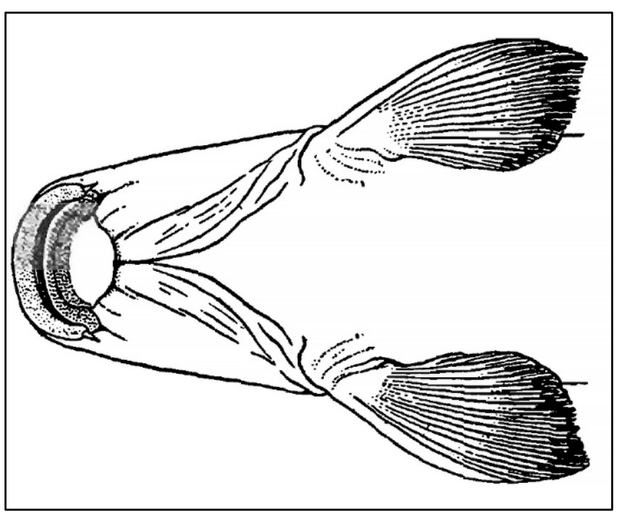
***Garra nudiventris***
(Berg, 1905)



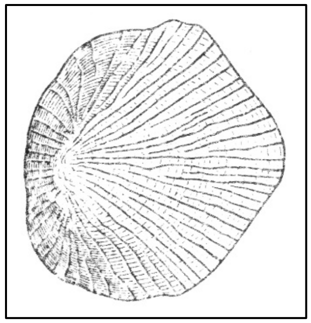
*Garra nudiventris*, 54.5 mm standard length, ZM-CBSU H1500,
South Khorasan, Kalat-e Baba Qanat, Birjand, Hamid Reza Esmaeili.



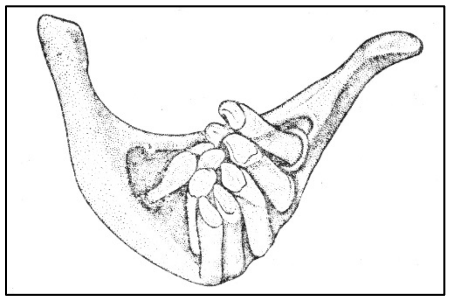
*Garra nudiventris*, 81 mm standard length, VMFC GND,
South Khorasan, qanat near Nehbandan, Hamed Mousavi-Sabet.



*Garra nudiventris* (as *Discognathus phryne*),
ventral head, after Annandale (1919).



*Garra nudiventris*
(as *Discognathus phryne*),
dorsolateral scale, after
Annandale and Hora (1920).



*Garra nudiventris*
(as *Discognathus phryne*),
pharyngeal teeth,
after Annandale and Hora (1920).

**Common names.** Gel cheragh shekam berahne (= naked belly mud-eater), gel cheragh Lut (= Lut mud-eater).

[Lut garra].

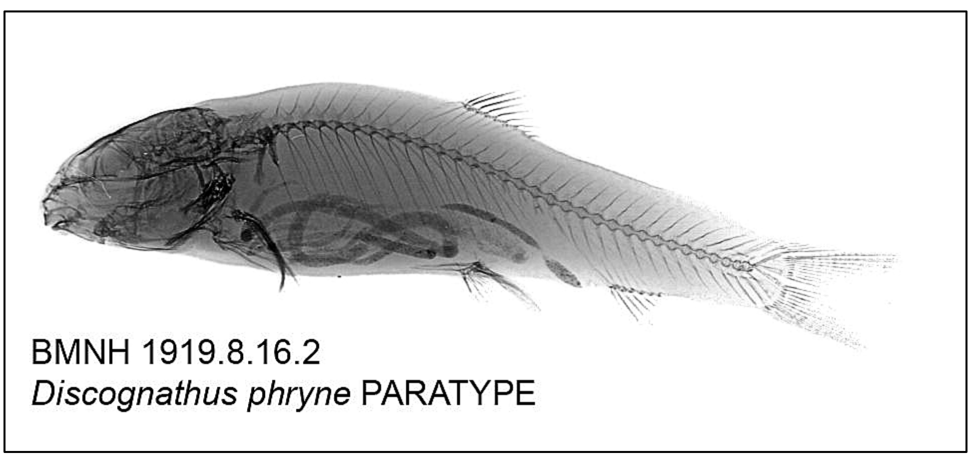
**Systematics.** *Discognathus rossicus* var. *nudiventris* Berg, 1905 was described from "Schiwar" (= Shivar) in Iran for specimens with a naked abdomen, thoracic region and groove on the back anteriorly. The distribution of these specimens overlaps with that of the type form and they were not previously given independent taxonomic recognition by me. Berg (1949) later placed them as an infraspecies. Esmaeili *et al*. (2016) recognised this taxon as a distinct species using both scalation and molecular characters. However, populations vary in scalation as detailed below and further work using additional characters is needed to clarify the taxonomy and for field identification. Mousavi-Sabet *et al*. (2019) re-assessed the taxonomic status of *G*. *nudiventris* and, in their molecular dataset, *G*. *rossica* was very closely related to *G*. *nudiventris*, and both were characterised by a minimum K2P distance of 0.46% in the COI barcode region. The two species separated clearly in two distinct clades despite the low genetic difference. All *G*. *rossica* examined were distinguished from all *G*. *nudiventris* by having the predorsal mid-line, the breast, and belly covered by scales versus naked in the aptly named *G*. *nudiventris*.

*Discognathus phryne* Annandale, 1919 described "from Seistan" and "irrigation channel at Nasratabad, Seistan" is a synonym (Berg, 1949). Menon and Yazdani (1968) gave Nasratabad, Seistan as the type locality. *D*. *phryne* was formerly placed in *G*. *rossica* before *G*. *nudiventris* was recognised as a distinct species (Coad, 1981c).

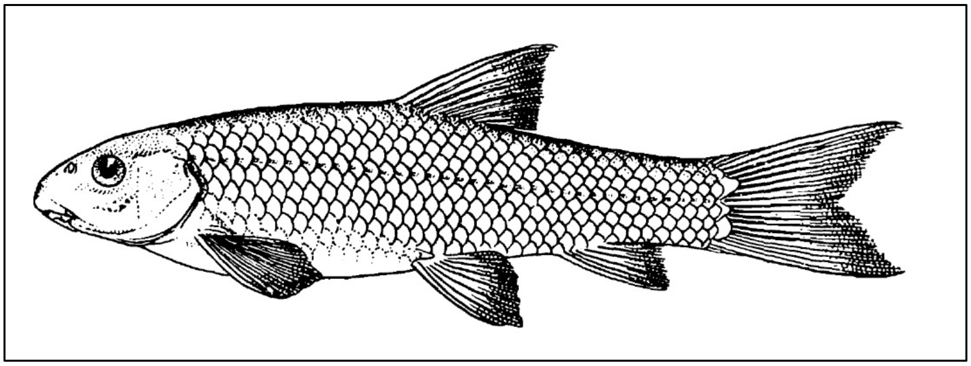
The types for var. *nudiventris* are in ZISP 11113, listed by Nikol’skii (1900) as four fish from “Schivar in Persia orient.”, by Berg (1905) as two fish from “Schivar”, and by Berg (1949) as four fish, not numbered in the ZISP catalogue but with five fish in the jar (45.6-66.2 mm standard length) as measured by me. Parts of ZISP 11703 and 11708 according to Berg (1949) are also types. ZISP 11708 was listed in Berg (1949) as 13 specimens and ZISP 11703 was not listed although Nikol’skii (1900) gave six for both. The type localities for var. *nudiventris* are for ZISP 11113 “Shivar, north of Nikh (Nekh), north-east Kerman, basin of L. Hamun, 23 VI 1896, N. Zarudnyi”, for ZISP 11708 “Podaghi, 28°08'N, north-north-east of Bazman, eastern Kerman, 6 VII 1898, N. Zarudnyi” according to Berg (1949) and ZISP 11703 is “Persia orientalis” according to Nikol’skii (1900) (the catalogue number ZISP 11703 does not appear under the description of materials in Berg (1949)). Shivar is at 31°52N, 59°55’E, and may actually be in the Dasht-e Lut basin not Sistan. Podagi is at 27°52'N, 60°41'E according to Roselaar and Aliabadian (2007) somewhat at odds with the above latitude but still roughly north-north-east of Bazman and in the Dasht-e Lut basin.

The holotype of *Discognathus phryne* is in the Zoological Survey of India, Calcutta (ZSI F9787/1) (Annandale, 1919b; Menon and Yazdani, 1968), a syntype (listed as a cotype) measuring 42.2 mm standard length from “Baluchistan” with the annotation “Ind. Mus. Ex. F 9789/1” is in the Natural History Museum, London (BM(NH) 1919.8.16:1) with another syntype (cotype) from “Quetta” measuring 32.2 mm standard length with the annotation “Ind. Mus. Ex. F 9790/1” (BM(NH) 1919.8.16:2).

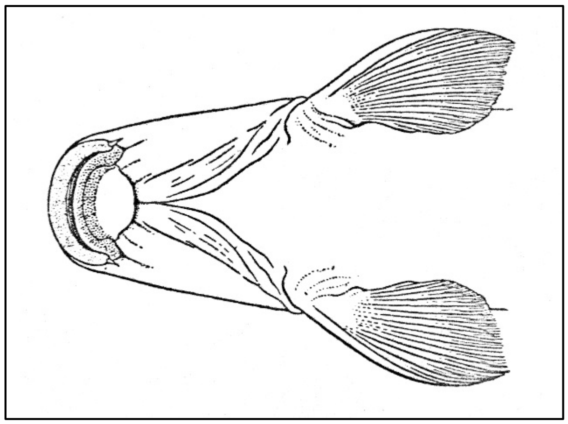

*Discognathus phryne*, paratype, BM(NH) 1919.8.16:2.




*Discognathus phryne*, Natural History Museum (2014)
(data.nhm.ac.uk), https://doi.org/10.5519/0002965, retrieved: 02 Feb 2019.



*Discognathus phryne*, type specimen, after Annandale (1919).



*Discognathus phryne*, type, ventral head,
after Annandale (1919).

**Key characters.** *Garra nudiventris* is distinguished from all other species of *Garra* in Iran except *G. mondica* (in the Mond River basin, Fars) by having the predorsal mid-line region and belly naked (versus fully covered by scales) (but see below).

**Morphology.** There is a very clear absence of scales on the upper back and back midline in front of the dorsal fin and belly scales are absent in fish from South Khorasan. Other material has dorsal midline scales but no belly scales (CMNFI 2007-0028 and CMNFI 2007-0029, listed as *G. cf. nudiventris* below). Southern Baluchestan fish have the back midline and belly scaled but Sistan fish have the upper back and back midline scaled and the belly scaled or partially scaled, absent anteriorly (individually variable).

The body is elongated, moderately compressed laterally, and more compressed in the region of the caudal peduncle. The dorsal head profile rises gently, flat or slightly convex, and more or less continuous with the dorsal body profile to the nape or about the middle between the nape and the dorsal fin origin. The ventral profile is more or less straight to the anal fin origin. The head is moderately large and depressed, with a slightly convex or flat interorbital distance, depth at the nape is less than head length, and width at the nape is greater or about equal to the depth at the nape. The eye is placed dorso-laterally in the anterior half of the head. Barbels are in one maxillary pair. The disc is weakly-developed with free lateral and posterior margins, slightly papillate. The disc is triangular, shorter than wide and narrower than head width through the base of the maxillary barbel. The rostral cap is developed, fimbriate, and papillate on the ventral surface. The upper jaw is almost or, completely, covered by the rostral cap. The distal margin of the dorsal fin is straight and in some specimens slightly concave, the

fin origin is slightly closer to the caudal fin base than to the snout tip or equidistant, the fin origin is anterior to the vertical from the pelvic fin origin, and the first branched ray is longest with the tip of the last branched ray not reaching a vertical from the anus. The caudal fin is forked with the lobe tips pointed. The anal fin is short, the first branched ray is the longest, the distal margin is straight or slightly concave, and the origin is closer to the pelvic fin origin than to the caudal fin base. The pectoral fin reaches back to a point 9-11 scales anterior to the pelvic fin origin, and its length is shorter than head length. The pelvic fin reaches to the anus, and its origin is closer to the anal fin origin than to pectoral fin origin and is below the second or third branched dorsal fin ray. Note that specimens from isolated qanats often show signs of inbreeding such as deformed fins and an irregular body shape.

Dorsal fin with 3 unbranched and 6-7 branched rays, rarely with two elongate unbranched rays thus reducing the branched ray count, anal fin with 3 unbranched and 5 branched rays, pectoral fin with 12-17 branched rays, and pelvic fin with 6-8 branched rays. Scales on the flank are regularly arranged. The lateral line is complete with 34-42 scales and 2-3 on the caudal fin base. Transverse scale rows above the lateral line are 6-7, scales between the lateral line and the pelvic fin origin 5-6, and scales around the caudal peduncle 16-18. The anus is 3-4 scales in front of the anal fin origin. There is one very short axillary scale at the base of the pelvic fin in some individuals, and 9-11 scales between the posteriormost pelvic fin base and the anus that in some specimens are embedded and uncountable. Berg (1949) described the types from Shivar as having only 3-4 rows of scales below the lateral line while fish from Podaghi had 6 rows. Lateral line scales may be enlarged to almost twice the size of ones immediately adjacent on the flank, be irregular in shape, and may have a posterior notch. Scales on the upper flank are often much smaller than those on mid-flank, or all these scales may be regularly arranged and of similar size. Scales can often be very irregular in shape but more normal scales are rounded with a very anterior focus, radii on all fields, most numerous posteriorly, and a moderate number of circuli. The exposed part of the scale has a thick skin layer, firmly attached. Total gill rakers number 10-15. The gill rakers reach the one below when appressed and rakers are often small and hard to discern at the anterior end of the arch.

Meristic values for Iranian specimens (omitting *G. cf. nudiventris* below) are:- dorsal fin branched rays 6(3) or 7(27), anal fin branched rays 5(30), pectoral fin branched rays 13(1), 14(9), 15(16), 16(3) or 17(1), pelvic fin branched rays 6(2), 7(21) or 8(7), lateral line scales 34(5), 35(10), 36(8), 37(6) or 38(1), total gill rakers 10(3), 11(6), 12(13), 13(4), 14(1) or 15(3), and pharyngeal teeth 2,35-5,3,2(3) or 2,4,5-5,32(1), with a sloping flattened crown. The paratype of *D. phryne*, BM(NH) 1919.8.16:2, has 36 vertebrae.

**Sexual dimorphism.** Males have scattered small tubercles on the operculum, head and back and on the anterior pectoral fin rays including the first unbranched ray. Fish caught as early as 14 November 1974 (CMNFI 2007-0027) are tuberculate.

**Colour.** Overall colour is a light brown to olive, darker dorsally fading to a silvery abdomen. There is a dark stripe on the mid-flank. Fins are speckled on the rays but there are no rows of spots.

**Size.** Reaches 73.6 mm standard length.

**Distribution.** This species is recorded from the Lut, Makran, Sistan, and possibly the Bejestan and Hamun-e Jaz Murian basins, often in qanats outside Sistan with some in small drainages on the borders between basins, e.g., CMNFI 2007-0025. In the Lut basin reported from Kalat-e-Baba Qanat and other qanats at Birjand, and at Nasratabad in the southern Lut (= presumably Nosratabad west of Zahedan and not Nasratabad in Sistan); in the Makran at Chanf

on the Kagu River and the headwaters of the Sarbaz River; and in the Sistan basin from qanats at Khvansharaf, Nehbandan and Shusf, at Shivar, in the neizar of the Sistan hamuns, and the Helmand Delta (Berg, 1949; Esmaeili *et al*., 2016; Mousavi-Sabet *et al*., 2019). Podaghi (28º08'N north-north-east of Bazman) was not located and may be in the southern Lut basin or the Hamun-e Jaz Murian basin (Berg, 1949). Berg (1949) also lists northeast Kerman in the Sistan basin but this may refer to the Lut basin as understood here. The two localities below listed as *G*. *cf*. *nudiventris* are in the Sistan basin.

**Zoogeography.** See under the genus.

**Habitat.** This species is found in rivers, streams, marshes, springs and qanats.

Habitat of *Garra nudiventris*, South Khorasan, Kalat-e Baba Qanat, Birjand, Hamid Reza Esmaeili.

**Age and growth.** Unknown.

**Food.** Unknown.

**Reproduction.** Unknown, although fish with 1.1 mm eggs have been collected on 14 November 1974 (CMNFI 2007-0027).

**Parasites and predators.** None reported from Iran.

**Economic importance.** None.

**Experimental studies.** None.

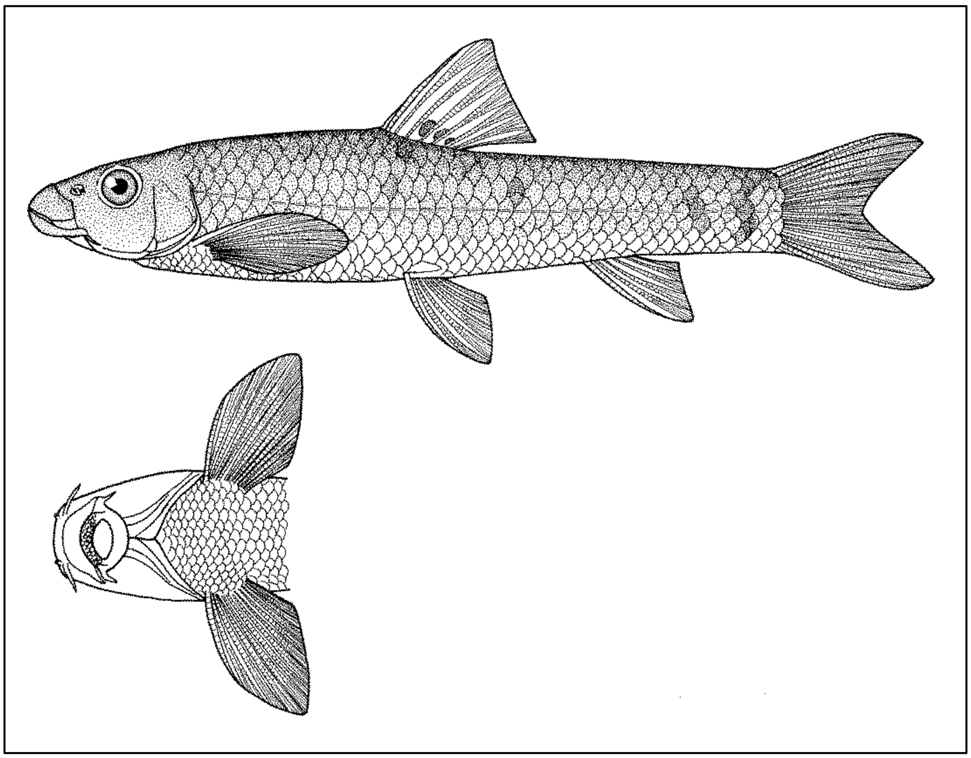
**Conservation.** Jouladeh-Roudbar *et al*. (2020) listed it as Data Deficient as they considered it to be known from only the Kalat-e Baba Qanat and its population status or distribution range in neighbouring countries was unknown.

**Sources.** Type material:- *Discognathus rossicus* var. *nudiventris* (ZISP 11113), *Discognathus phryne* (BM(NH) 1919.8.16:2).

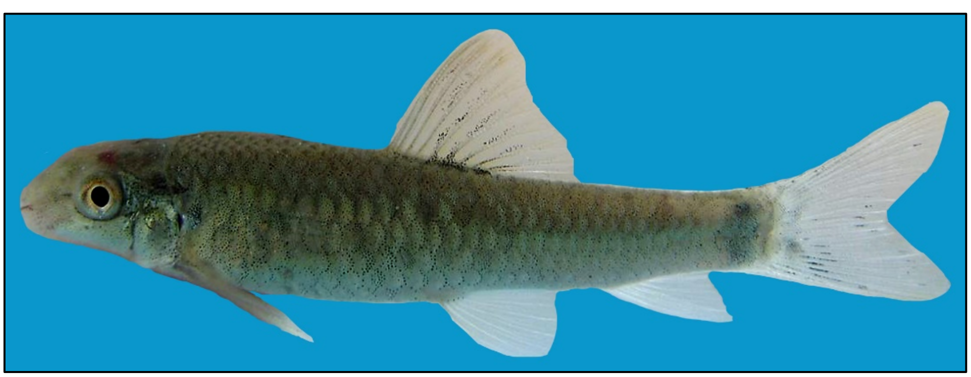
Iranian material:- CMNFI 1979-0091, 5, 24.7-57.2 mm standard length, South Khorasan, qanat at Nehbandan (31º32'N, 60º02'E); CMNFI 2007-0025, 8, 36.1-46.4 mm standard length, South Khorasan, qanat 120 km south of Birjand (ca. 32º24'N, ca. 59º49'E); CMNFI 2007-0026, 19, 36.2-63.2 mm standard length, South Khorasan, qanat at Shushf

(31º48'N, 60º01'E); CMNFI 2007-0027, 13, 30.7-60.3 mm standard length, South Khorasan, qanat at Khvanshahr (31º34'N, 60º06'E); CMNFI 2008-0197, 1, 73.1 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0199, 1, 73.0 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E); CMNFI 2008-0200, 1, 68.3 mm standard length, South Khorasan, Birjand qanats (32º52'N, 59º12'E).
*Garra cf. nudiventris*: CMNFI 2007-0028, 13, 36.3-58.9 mm standard length, South Khorasan, qanat at Khunik-e Pa'in (31º28'N, 60º06'E); CMNFI 2007-0029, 7, 35.2-60.7 mm standard length, Baluchestan, qanat at Hormak (29º58'N, 60º51'E).

## *Garra persica*
Berg, 1914



*Garra persica*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Garra persica*, 46.7 mm standard length, ZM-CBSU H1546, Hormozgan, Shur River, Hamid Reza Esmaeili.

*Garra persica*, Hormozgan, Gadegaz Stream near Bastak, Azad Teimori.

**Common names.** Mahi-ye sanglis-e Irani (= Iranian slippery rock fish), gel cheragh-e Parsi (= Persian mud-eater).

[Persian garra, Persian stone lapper].

**Systematics.** This species was recognised only as a subspecies of *Garra rufa* by Bianco and Banarescu (1982) while Menon (1964) and Karaman (1971) synonymised it with *Garra rufa*. Coad (1982b) recognised this species as distinct, principally on the unusual count of caudal fin rays. Karyotype analysis separated this species from *Garra rufa* (Esmaeili *et al*., 2009). Molecular evidence also separated this species (Hashemzadeh Segherloo *et al*., 2017) who also noted the presence of a non-disc bearing *G. cf. persica* from the Kesh River in the Makran. This latter may represent a new taxon or simply an odd variant. Variants are known to occur in other cyprinoid species where a certain character can be lost in a given population or group of individuals.

The syntype specimens are in the Zoological Institute, St. Petersburg under catalogue numbers ZISP 11707 (six specimens from the "River Bampur in Eastern Persia. N. Zarudnyi 1898, 15-27.VII") and 11706 (one specimen from "Kiabad in Zirkuh (Eastern Khorassan). N. Zarudnyi 1898, 3.V") according to Berg (1914) where the original description was founded on these fish, implying all are types. The latter was also given as "settlement Kiabad between Zirkuh province and Sistan" in the catalogue (this locality may be at or near Zir-e Kuh or Kuh-e Ziri at 32°48'N, 59°50'E according to Coad (1981c) and possibly in the Daqq-e Tondi basin). These dates are old style and corrected to new in Berg (1949) (27.VII-8.VIII and 15.V respectively). In St. Petersburg under ZISP 11707 there are 10 fish 24.0-46.5 mm standard length and ZISP 11706 is not listed as a type in the catalogue nor in Berg (1949). Berg (1949) listed 10 fish in 11707 too. These specimens were formerly identified as *Discognathus lamta* by Nikol'skii (1899) who listed one fish in 11706 and six in 11707. Three syntypes are in the Zoological Survey of India, Calcutta (ZSI F11101/1) listed under *Garra rufa obtusa* and received from the Zoological Institute, St. Petersburg, Russia on exchange (Menon and Yazdani, 1968). There are more apparent types available than those listed by Berg (1914) although the *Catalog of Fishes* (downloaded 15 May 2018) listed the ZSI material as questionably non-types.

**Key characters.** Two pairs of barbels are present, the adhesive disc is well-developed with a free posterior margin, the dorsal fin has 7 branched rays, and the caudal fin modally 16 branched rays. The caudal fin ray count is unique in cyprinoids from Iran and very rare elsewhere. Almost all cyprinoids show a strong mode of 17 branched caudal fin rays.

**Morphology.** The body is elongated, moderately compressed laterally, and more compressed in the region of the caudal peduncle. The dorsal head profile rises gently, flat or

slightly convex, and more or less continuous with the dorsal body profile to the nape or about the middle between the nape and the dorsal fin origin. The ventral profile is more or less straight to the anal fin origin. The head is moderately large and depressed, with a slightly convex or flat interorbital distance. The height at the nape is less than the head length. Head width at the nape is longer, or about equal to, the depth at the nape. The eye is placed dorso-laterally in the posterior (figures indicate anterior) half of the head. Barbels are in two pairs, the rostral barbel antero-laterally located, shorter or about equal to eye diameter, and the maxillary barbel at the corner of the mouth, shorter than the rostral barbel. Barbels are short. There is a well-developed disc with free lateral and posterior margins. It is heavily papillate with batteries of fleshy papillae arrayed around the periphery of the whole disc. The disc is elliptical, shorter than wide and narrower than head width through the base of the maxillary barbel. The rostral cap is well-developed, weakly fimbriate, and papillate on the ventral surface. The upper lip is present and well-developed as a thin band of papillae arranged in two ridges. The upper jaw is almost or completely, covered by the rostral cap. The dorsal fin distal margin is concave, the fin origin is closer to the snout tip than to the caudal fin base or equidistant in some specimens, the origin is anterior to the vertical from the pelvic fin origin, the first branched ray is the longest, and the tip of the last branched ray reaches a vertical from the anus. The caudal fin is forked with lobe tips pointed. The anal fin is short with the first branched ray the longest, the distal margin is straight or slightly concave, and the origin is closer to the pelvic fin origin than to the caudal fin base. The pelvic fin reaches back to the anus, its origin is closer to the anal fin origin than to pectoral fin origin, and the origin is below the second or third branched dorsal fin ray. The pectoral fin reaches back to a point 5-7 scales anterior to the pelvic fin origin and its length is shorter than head length. The above was based mostly on Esmaeili *et al*. (2019).

Dorsal fin with 4 unbranched and 6-8 branched rays and a strong mode at 7, anal fin with 2-3 unbranched and 4-6 branched rays with a strong mode at 5, pectoral fin branched rays 12-16, pelvic fin branched rays 6-8, and caudal fin branched rays 15-17 with a strong mode at 16. Scales on the flank are regularly arranged. Lateral line scales 28-40, transverse scale rows above the lateral line 4, between the lateral line and the pelvic fin origin 4, scales around the caudal peduncle 14-16, and usually 14-17 scales on the predorsal midline in front of the dorsal fin. The chest has embedded scales, and the belly is covered by scales, only lacking on the anterior isthmus in some fish. There is a short axillary scale at the base of the pelvic fin in some individuals, and 5-7 scales between the posteriormost pelvic fin base and the anus. The anus is 2-3 scales in front of the anal fin origin. Scale shape is roundish, the posterior margin is rounded and protruding or a shallow curve, the dorsal and ventral margins are gently rounded, the anterior corners are rounded, and the anterior margin has a weak and shallow to evident central protrusion with an indentation above and below or is wavy with 3-4 protrusions. Scales have numerous radii on all fields with the focus broken up into a network of lines. Zareian and Esmaeili (2015) observed abnormal scales such as fusions, two foci and lateral line deformations. Total gill rakers number 15-22 with lower counts in smaller fish. Pharyngeal teeth are usually 2,4,5-5,4,2. The gut is very elongate and greatly coiled. Total vertebrae number 32-36. Chromosome number 2n = 48 with 15m, 8Sm and 1St (Esmaeili *et al*., 2009).

Zamani Faradonbe and Keivany (2017) described the osteology of this species. Zareian *et al*. (2021) described scale abnormalities from fish in the Gahkom and God Gaz rivers of the Kul River basin.

Counts for 12 Iranian topotypic specimens from the Bampur River are:- dorsal fin with

4(12) unbranched and 7(12) branched rays, anal fin with 3(12) unbranched and 4(3) or 5(9) branched rays, pectoral fin branched rays 12(1), 13(6) or 14(4), caudal fin branched rays 15(1), 16(8) or 17(1) in the type series and 15(1), 16(10) or 17(1) in topotypes, lateral line scales 29(2), 30(1), 31(1), 32(2), 33(2), 34(2) or 35(2), total gill rakers 15(6), pharyngeal teeth 2,4,5-5,4,2(5), and total vertebrae 34(9) or 35(3).

Meristic values for topotypes and other material:- dorsal fin branched rays 6(3), 7(115) or 8(4), anal fin branched rays 4(5) or 5(118), pectoral fin branched rays 12(8), 13(40), 14(49), 15(20) or 16(5), pelvic fin branched rays 6(9), 7(100) or 8(13), caudal fin branched rays 15(10), 16(113) or 17(9), lateral line scales 28(1), 29(5), 30(5), 31(77), 32(18), 33(28), 34(20), 35(22), 36(11), 37(4) or 38(2), total gill rakers 15(16), 16(13), 17(18), 18(17), 19(11), 20(4) or 21(2), pharyngeal teeth 2,4,5-5,4,2(5), and total vertebrae 32(4), 33(44), 34(34) or 35(4).

**Sexual dimorphism.** Males develop numerous breeding tubercles around the snout, between the nostril and the eye and between the nostrils. There is a transverse depression anterior to the nostrils on the snout. A post-spawning individual from the Hormuz basin measuring 31.5 mm standard length (CMNFI 1979-0187, 29 January 1977) has small tubercles under the eye running forward onto the snout as a band, the most evident tuberculation. The swollen snout tip bears no tubercles. The top of the head has tubercles but these are smaller and sparser than the band under the eye. Scattered large tubercles are present on the gill cover. Evident tubercles line the dorsal, anal, caudal and pectoral fin rays (pelvic fins not present on specimen), the largest being those on the anal fin.

**Colour.** The back and flanks are an orange-brown to golden-brown. There is a blue spot on the flank near the postero-dorsal edge of the operculum (dark black in preserved fish). The dorsal fin bears elongate blotches on the posterior half of each fin membrane, usually fading distally, but in some fish occupying the whole membrane. Proximally there is a gap between these blotches and 3-5 bars which originate at the posterior edge of the base of branched ray three and succeeding rays, and extend distally across the ray and then along the ray and the membrane to the gap. These bars are much more heavily pigmented than the dorsal blotches. There is a bluish tinge or spot around the pectoral fin base, sometimes developed as a bar along the edge of the gill cleft, becoming dark blue dorsally. There is a dark bar or a roundish, poorly-delimited spot on the caudal peduncle at the base of the caudal fin. Fins are generally pink to light orange but in some are reddish. The caudal fin pigmentation is individually variable. Some are blotched irregularly on both rays and membranes, in others there is a trace of a band in mid-fin extending from the dorsal to the ventral margin following the posterior outline of the fin, while others have pigment heavily concentrated only in the mid-fin clear of the margins. The pelvic fin has little or no pigment and the anal fin has a very few irregular light blotches on both rays and membranes. The pectoral fin is pigmented near the dorsal base with some pigment on anterior rays and membranes. In live fish, the paired fins are a light orange and other fins show less marked orange tinges. The peritoneum is black.

**Size.** Attains 9.95 cm total length (Esmaeili *et al*., 2014).

**Distribution**. This species is found in the Hamun-e Jaz Murian, Hamun-e Mashkid Hormuz and Makran basins and possibly the Kerman-Na'in and Sistan basins (Bianco and Banarescu, 1982; Abdoli, 2000; Zamani-Faradonbe and Keivany, 2021b). It is widely distributed in springs and qanats not all named here. In the Hamun-e Jaz Murian basin in the Bampur, Halil and Karvandar rivers, qanats at Abtar, Bazman and Mirabad, and the Bampur Dam; in the Hamun-e Mashkid basin in the Zaminbandan Stream; in the Hormuz basin in the Gahkom, Galehgah, Gadegaz or God Gaz, Gowdeh, Hajiabad, Kul, Mehran, Rasul, Sarzeh,

Shur and Tas rivers, in the Sar Khun oasis and in the Ab Garm-e Ganow hot spring; in the Makran basin in the Geru, Jaghin, Kash, Minab, Qabrik, Rudan, Sandrak and Sarbaz rivers; and in the Sistan basin from the Zahak River (Ebrahimi, 2001; Ebrahimi *et al*., 2002; Bagheri *et al*., 2010; Jalili and Eagderi, 2014b; Esmaeili *et al*., 2015; Sayyadzadeh *et al*., 2015; Mousavi-Sabet *et al*., 2019; Zamani-Faradonbe and Keivany, 2021a, 2021b; Zareian *et al*., 2021). Zamani-Faradonbe and Keivany (2021a) also reported this species from the Firouzabad and Karzin tributaries of the Mond River of the Persis basin but this needs confirmation.

**Zoogeography.** The species of the genus *Garra* were thought by Menon (1964) to have colonised Iran from a centre of origin in southern China by a series of "waves". The earliest wave arrived in the Miocene and is represented in Iran today by the species *rossica* and *variabilis*, characterised by the primitive condition of a weakly-developed adhesive disc without a free posterior, the posterior chamber of the gas bladder cylindrical and well-developed, no proboscis on the snout, and the vent is close to the anal fin. A second wave is represented in Iran by *rufa* (and by implication *persica*) characterised by a well-developed disc and a tuberculated snout marked off by a transverse groove. There were six "waves" all told but only the first two are relevant to Iran. Karaman (1971) criticised this complex interpretation on two grounds. He maintained that it is unlikely that fishes would immigrate from southern China to Iran but leave no extant forms between these two remote places and that the species assigned to the various waves showed no characteristics which would make them more adaptive and capable of replacing earlier wave members. The characters of *rossica* and *variabilis* (one pair of barbels, weak disc, and reduced squamation) could equally be loss characters and a more recent specialisation rather than the primitive condition. See also under the genus.

**Habitat.** This species is found in rivers, streams, dams, ponds, springs and qanats, and in brackish waters. Kiabi and Abdoli (2000) found this species to have the widest altitudinal range in Hormozgan Province. In the Ginao or Ganow hot spring below the falls, this species was caught at 31-36°C (CMNFI 1979-0416). Collection data included a temperature range of 18-36ºC, pH 6.0-7.0, conductivity 0.8-28 mS, river width 0.5-15 m, slow to medium current, capture depth 20-400 cm, clear water, mud, sand, gravel, stone, pebble, boulder or bedrock bottoms, encrusting and submergent vegetation including filamentous algae, and a grassy or forested shore.

Habitat of *Garra persica*, CMNFI 1979-0416, Hormozgan, Ab Garm-e Ganow,
21 March 1978, Brian W. Coad.

Habitat of *Garra persica* (and *Cyprinion watsoni*), CMNFI 1979-0138,
Fars, stream in Rasul River drainage, 20 November 1976, Brian W. Coad.

**Age and growth.** Esmaeili *et al*. (2014) gave a *b* value for 15 fish from the Hormuz basin, 5.92-9.95 cm total length, as 2.79. Saemi Kamsari *et al*. (2018) gave a *b* value of 3.32 for fish from Hormozgan, positive allometric growth.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** This species is widely distributed in various smaller water bodies in eastern Iran and does not appear to be under threat. Yousefi *et al*. (2018a) however found that only 10% of the desirable habitats for this species were in protected areas. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern because of its large distribution range, abundance and lack of widespread threats.

**Sources.** Type material:- *Garra persica* (ZISP 11706 and 11707).

Iranian material:- CMNFI 1979-0138, 1, 25.7 mm standard length, Fars-Hormozgan border, stream in Rasul River drainage (ca. 27º32'N, ca. 54º58'30"E); CMNFI 1979-0139, 1, 30.6 mm standard length, Fars-Hormozgan border, stream in Rasul River drainage (ca. 27º25'30"N, ca. 54º59'E); CMNFI 1979-0144, 1, 27.3 mm standard length, Hormozgan, Minab River at Minab (27º09'30"N, 57º04'E); CMNFI 1979-0145, 4, 14.8-25.4 mm standard length, Hormozgan, Geru River south of Minab (26º55'N, 57º01'30"E); CMNFI 1979-0149, 7, 29.0-49.4 mm standard length, Hormozgan, stream north of Bandar-e Abbas (27º36'N, 56º14'E); CMNFI 1979-0152, 1, 62.2 mm standard length, Hormozgan, Shur River drainage (28º09'N, 55º43'E); CMNFI 1979-0178, 23, 25.1-66.9 mm standard length, Hormozgan, Sarzeh River drainage (27º36'N, 56º15'E); CMNFI 1979-0180, 1, 42.7 mm standard length, Hormozgan, stream 3 km east of Essin (27º19'N, 56º17'30"E); CMNFI 1979-0181, 1, 44.0 mm standard length, Hormozgan, Kul River (27º17'30"N, 56º03'30"E); CMNFI 1979-0186, 8, 30.2-64.6 mm standard length, Hormozgan, stream and pools at Sar Khun (ca. 27º24'30"N, ca. 56º25'E); CMNFI 1979-0187, 9, 32.1-57.9 mm standard length, Hormozgan, stream and pools at Sar Khun (27º23'30"N, 56º26'E); CMNFI 1979-0312, 10, 26.6-35.6 mm standard length, Baluchestan, dam on Bampur River (27º11'N, 60º36'E); CMNFI 1979-0315, 1, 23.8 mm standard length, Baluchestan, Bampur River 2 km north of Karvandar (27º51'N, 60º46'E); CMNFI 1979-0324, 1, 29.6 mm standard length, Baluchestan, Bampur River at Sa'idabad (27º11'N, 60º22'E); CMNFI 1979-0329, 2, 25.4-30.8 mm standard length, Baluchestan, stream at Zaminbandan (27º02'N, 61º20'E); CMNFI 1979-0411, 1, 60.4 mm standard length, Hormozgan, Minab River (27º24'N, 57º12'E); CMNFI 1979-0412, 9, 22.9-39.3 mm standard length, Hormozgan, spring at Saras (27º30'N, 57º34'E); CMNFI 1979-0416, 39, 15.1-46.8 mm standard length, Hormozgan, Ab Garm-e Ganow (ca. 27º26'N, ca. 56º20'E); CMNFI 2007-0051, 10, 29.5-43.7 mm standard length, Hormozgan, upper Kul River basin (28º19'N, 55º55'E); CMNFI 2007-0055, 5, 30.9-44.6 mm standard length, Hormozgan, Minab River basin (27º47'N, 57º12'E); CMNFI 2007-0056, 2, 32.1-54.2 mm standard length, Kerman, qanat at Kahnuj (27º58'N, 57º45'E); CMNFI 2007-0058, 7, 36.7-51.7 mm standard length, Fars, headwaters of Gowdeh River (ca. 27º24'N, ca. 54º16'E); CMNFI 2008-0142, 1, not kept, Hormozgan, Jaghin River (27º12'N, 57º25'E).

## *Garra roseae*

Mousavi-Sabet, Saemi-Komsari, Doadrio and Freyhof, 2019

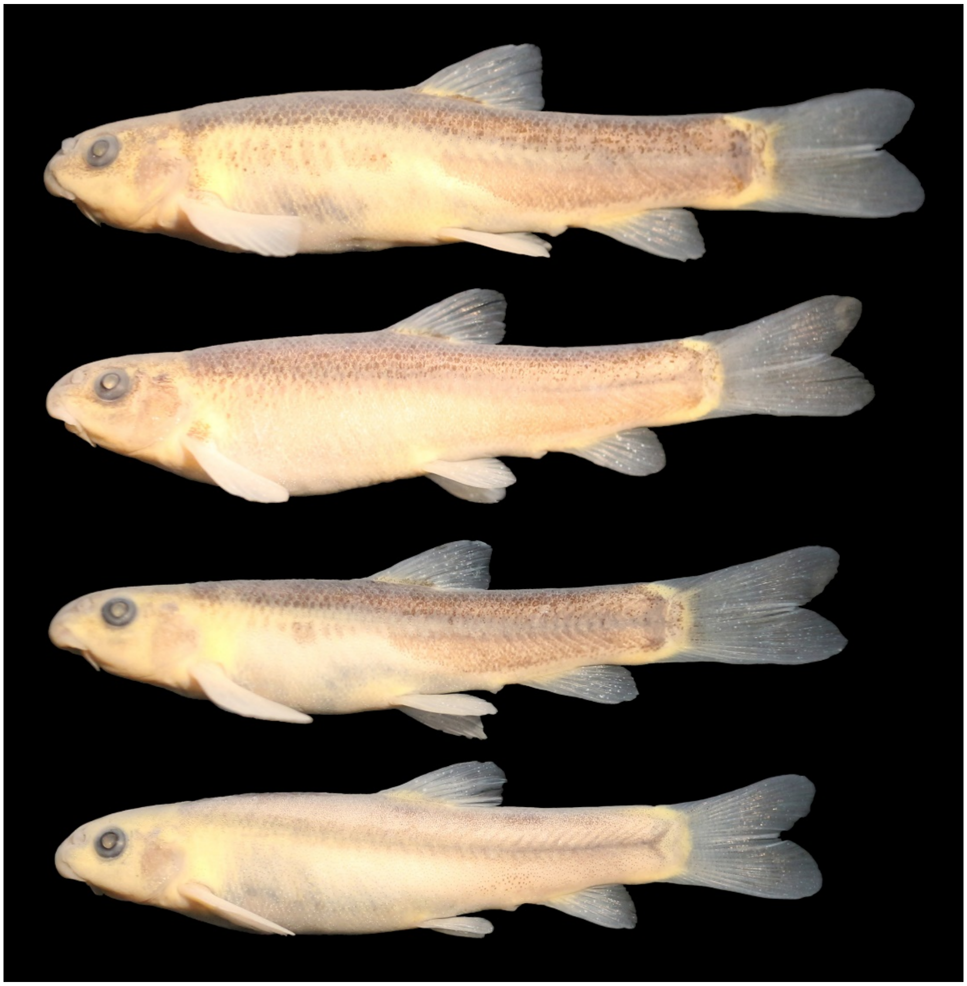
*Garra roseae*, 45.6 mm standard length, CMNFI 1979-0327,
Marie-Hélène Hubert @ Canadian Museum of Nature.

*Garra roseae*, paratype, 36.0 mm standard length, VMFC GR-P1122,
Hamed Mousavi-Sabet.

**Common names.** Gel cheragh-e Makran (= Makran mud-eater).
[Makran garra].

**Systematics.** The holotype is under GUIC (Guilan University Ichthyological Collection, Sowmeh-Sara) 7847, 38.0 mm standard length, Sistan-va-Baluchistan Province, stream Tang-e-Sarhe near Siahangari, at km 465 on road from Zahedan to Chabahar, 26.5383ºN, 59.9406ºE, with paratypes under VMFC (Vatandoust and Mousavi-Sabet Fish Collection, Tehran) GR-P1122, 22, 31.0-51.0 mm standard length and FSJF (Fischsammlung J. Freyhof, Berlin) 4071, 4, 34.0-37.0 mm standard length, both same data as the holotype. The species is named after the first author’s daughter, Rose.

*Garra roseae*, holotype, GUIC 7847, Hamed Mousavi-Sabet.



*Garra roseae*, paratypes, 36.0 mm, 35.0 and 34.0 mm standard length,
VMFC GR-P1122, Hamed Mousavi-Sabet.

**Key characters.** This species is distinguished by lacking barbels, having a small mental disc, and by scale counts. Data on the mtDNA COI barcode region also separates this species from its relatives.

**Morphology.** This is a small-sized and elongated species with a laterally compressed caudal peduncle. The dorsal head profile rises gently and is slightly convex. The predorsal contour is slightly convex between the nape and the dorsal fin origin. The prepelvic contour is convex, and the ventral profile is more or less straight from the pelvic fin origin to the anal fin origin. The body is deepest at about the dorsal fin origin or about the middle between the nape and the dorsal fin origin, the depth decreasing towards the caudal fin base. The greatest body width is at the pectoral fin base, the body is almost equally wide until the dorsal fin origin, with the width decreasing towards the caudal fin base. The caudal peduncle length is 1.1-1.5 times longer than deep. The head is moderately small, the head section is roundish, flattened on the ventral surface, and slightly depressed, almost conical. The interorbital space is slightly convex or flat. The height at the nape is shorter than the head length. The width at the nape is greater or about equal to the depth at the nape. Head length is 0.8-1.1 times in body depth. The snout is rounded, its length 1.2-1.6 times in postorbital length. There is no obvious tubercle on the transverse lobe. The snout is demarcated posteriorly by a shallow transverse groove in some

individuals, and no transverse groove in others. There is no obvious tubercle on the proboscis and the lateral surface of the snout. The depressed rostral surface is always without tubercles, moderately separates the transverse lobe from the lateral surface, and is not clear in some specimens. There is no groove between the transverse lobe and the lateral surface. The eyes are relatively large, eye diameter is 2.3-2.9 times in head depth at the eye, and 2.0-2.3 times in the interorbital width. The eyes are located dorso-laterally on the anterior half of the head or at mid-head. The rostral cap is well-developed, fimbriate, and papillate on the ventral surface. An upper lip is present. The upper jaw is almost, or completely, covered by the rostral cap. The disc is elliptical, shorter than wide and narrower than the head width. Papillae on the anterior fold are of the same size, regularly arranged. A groove between the antero-median fold and central callous pad is narrow and deep, and the latero-posterior flap is absent. The surface of the central callous pad is without, or with, sparsely arranged small papillae. The posterior margin of the central callous pad extends to the vertical from the anterior edge of the eye. The nostrils are located just anterior to the eyes, and are round-shaped. The anterior nostril opening is developed as a low, pointed and flap-like tube. The posterior nostril is narrow, nostrils are adjacent, and the posterior tip of the anterior nostril reaches to the posterior nostril when folded down. The last unbranched ray of the dorsal fin is shorter than the head length. The margin of the dorsal fin is slightly concave or straight and the fin origin is closer to the caudal fin base than to the snout tip. The dorsal fin is inserted (*sic*, dorsal fin origin is meant probably) anterior to the vertical from the pelvic fin origin. The first branched ray is the longest, and the tip of the last branched ray reaches the vertical to, or slightly in front of, the anus when folded down. The caudal fin is forked with the lobe tips rounded or slightly pointed. The caudal fin is emarginated (length of the ray in the middle of fin 68-72% of the longest branched ray in the upper lobe of the fin). The anal fin is short, the first branched ray being the longest. The margin is straight or slightly convex and the origin is closer to the pelvic fin origin than to the caudal fin base. The anal fin reaches back approximately to a half or three-quarters of the caudal peduncle when folded or almost to the caudal fin procurrent rays. The pelvic fin does not reach back to the anus, or reaches the anus in some individuals, and its origin is closer to the anal fin origin than to the pectoral fin origin and below the third or fourth branched dorsal fin ray. The pectoral fin reaches approximately 38-54% of the distance from the pectoral fin origin to the pelvic fin origin, and its length is shorter than the head length.

Dorsal fin with 3 unbranched and 6-8, usually 7, branched rays, anal fin with 3 unbranched and 5 branched rays, pectoral fin with 10-14 branched rays, and pelvic fin with 7-9 branched rays. Lateral line scales 38-58 (42-58 in type description so wide-ranging as confirmed by my fish below), of which 2-3 are on the caudal fin base. Transverse scale rows above the lateral line 7-11, between the lateral line and the pelvic fin origin 6-8, between the lateral line and the anal fin origin 6-10, and circumpeduncular scale rows 20-28. Usually, there are 24-30 scales on the predorsal midline between the dorsal fin origin and the nape, embedded in some specimens, and 20-27 along the side of the midline. Scales on the flank are regularly arranged. The chest is naked and the belly scaled (scales present from the mid-level of the pectoral fin when folded back). There is no axillary scale at the base of the pelvic fin. The lateral line is complete. Scales are rounded and have a subcentral anterior focus, radii on all fields and numerous fine circuli. Total gill rakers number 10-13. Pharyngeal teeth are 2,4,5-5,4,2 with an oblique but flattened crown which is slightly concave, and with a slight hook on the smaller teeth. Total vertebrae number 35-36.

Meristic values are:- dorsal fin branched rays 7(5), anal fin branched rays 5(5), pectoral

fin branched rays 13(2) or 14(3), pelvic fin branched rays 7(1), 8(3) or 9(1), lateral line scales 38(1) …., 46(1) …., 50(1) …., 55(1) …. or 58(1), predorsal scales 20(2), 24(1) or 27(2), scales above the lateral line 7(1), 10(3) or 11(1), scales below the lateral line to the pelvic fin 6(1), 7(1) or 8(3), scales below the lateral line to the anal fin 7(1), 8(1), 9(2) or 10(1), and scales around the caudal peduncle 20(1), 21(1), 26(2) or 28(1), total gill rakers 10(1), 11(2) or 12(2), and total vertebrae 35(3) or 36(2).

**Sexual dimorphism.** Head tubercles are present only on the opercular surface and are small and scattered. The first unbranched and three branched pectoral fin rays are also lined with small tubercles.

**Colour.** In preserved individuals, the background colour is light brown, pale yellowish or whitish. Scales are brown with whitish or yellowish margins. The dorsal surface of the head is pale yellow or brown. The flank above the lateral line is dark or pale brown. The abdominal edge and caudal fin origin are pale yellow. The lateral head and flank anterior to the dorsal fin base are pale yellow to whitish below the lateral line. The cheek is pale yellowish or whitish. A faint, irregularly shaped, grey inner axial stripe is most prominent on the flank behind the dorsal fin base. The mouth, chest and abdomen are yellowish. A wide, often indistinct, black or dark-brown bar is on the posterior-most caudal peduncle, faded in most individuals, and up to 2-3 scales wide. The bar reaches the dorsal midline in some individuals, not reaching the ventral midline. The lateral line is beige, in contrast to the brown colour on the mid-lateral flank. There is a dark-brown blotch at the base of unbranched dorsal fin rays, followed by a beige base to branched rays 2-3, and a black or dark brown base to rays 4-7. All fins are hyaline with irregularly set black spots on the rays. In life, the background colour is silvery, and all fins are hyaline with irregular black spots. The head is grey and scales on the flank and back are dark grey, and whitish or pale grey on the lower flank and belly. The iris is silvery-orange with dark grey spots, the internal ring without spots. There are dark grey dots at the pectoral fin base in some individuals.

**Size.** Reaches 5.1 cm standard length.

**Distribution.** This species is found in the Tang-e Sarhe Stream in the Makran basin.

**Zoogeography.** See generally under the genus. This species is related to *G. nudiventris* and *G. rossica*, other eastern Iranian species, in the *G. variabilis* group.

**Habitat.** The only known locality is a shallow stream with slow current at 1,116 m altitude.

Habitat of *Garra roseae*, Baluchestan, Tang-e Sarhe Stream, Hamed Mousavi-Sabet.

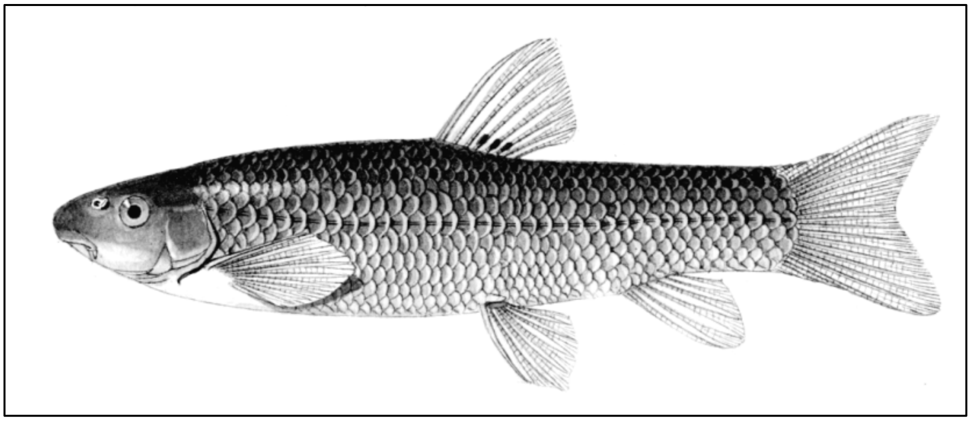
**Age and growth.** Unknown.
**Food.** Unknown.
**Reproduction.** Unknown.
**Parasites and predators.** None reported.
**Economic importance.** None**.**
**Experimental studies.** None

**Conservation.** Distribution is limited to a single stream and so the species is open to loss from deleterious events. The type locality was polluted from villages along the 70 km long stream. Jouladeh-Roudbar *et al*. (2020) listed it as Data Deficient.

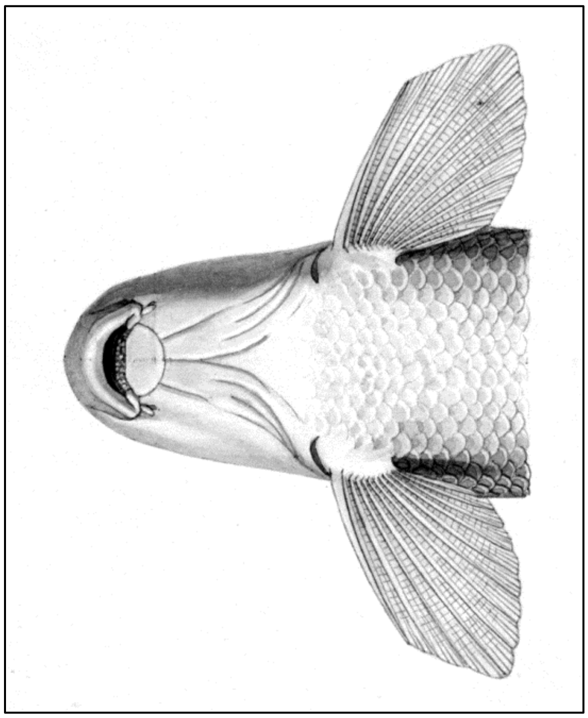
**Sources.** Based mainly on Mousavi-Sabet *et al*. (2019).

Iranian material:- CMNFI 1979-0327, 5, 37.3-46.7 mm standard length, Baluchestan, stream in Geh (= Kahir) River drainage (26º32'N, 59º57'E) (this may be the same stream as the type locality).

***Garra rossica***
(Nikol'skii, 1900)



*Garra rossica*, ca. 8.8 cm total length, ZISP 13022,
Turkmenistan, Tedzhen River, after Berg (1948-1949).



*Garra rossica*, ventral head, as above,
after Berg (1948-49).

*Garra rossica*, 41.9 mm standard length, ZM-CBSU N168, Baluchestan, Irandegan River,
Hamid Reza Esmaeili.

*Garra rossica*, 86.0 mm standard length, VMFC GROS, Razavi Khorasan, Golbahar Spring, Hamed Mousavi-Sabet.

**Common names**. Mahi-ye sangi (= rock or stone fish), mahi-ye sang lis (= slippery rock fish or rock scraper), mahi-ye sanglis-e rosy (= rosy rock scraper, Y. Keivany, pers. comm., 25 September 2018), rosy stone lapper (Zamani-Faradonbe and Keivany, 2021b.), gel cheragh-e Ross (= after Jouladeh-Roudbar *et al*. (2020), probably rus for Russian was meant so Russian mud-eater), gel cheragh-e Hari (= Hari River mud-eater), anjarak.

[Diskognat in Russian; pathar chat or patherchatta in Pakistan; Hari garra, Russian garra, rosy stone lapper].

**Systematics.** *Garra rossica* has been placed in the genera *Discognathus* Heckel, 1843 and *Discognathichthys* Bleeker, 1859, here considered to be synonyms of *Garra*.

The syntypes of *Discognathus rossicus* are in the Zoological Institute, St. Petersburg (ZISP 10365), the type locality in Latin on page 239 being "Flum. Tedschent in prov. Transcasp. Zarudnyi. 1892 (4)" while on p. 240 are the localities "Habitat in flumine Tedshent in provincia Transcaspiensi, nec noc in Persia orientale ad Kirmanum orientale" (Nikol'skii, 1900), and confirmed by me (Tedzhen River and eastern Persia to eastern Kirman). However, there were three fish in the jar (45.0-54.5 mm standard length) although four are listed in the catalogue and in the type description. Berg (1905) listed three fish but in Berg (1949) listed only two. Other materials listed by Nikol'skii (1900) from eastern Iran and Kerman (ZISP 11113, 11703, 11704, 11705, 11708) are apparently syntypes too. Eschmeyer *et al*. (1996) also listed ZIL (= ZISP) 10665 (4) as part of the type series, perhaps a misprint for ZISP 10365. The *Catalog of Fishes* (downloaded 30 June 2019) lists syntypes as 10365 [not 10665, thus correcting the earlier work] (4, now 3), 11113 (6), 11703-05 (6+, 6, 6) and 11708 (6). Some syntypes under ZISP 11703 are now types for *G. nudiventris* (*q.v*.).

Pavlov *et al*. (1994) contains a reference to *Garra* in the Tedzhen and Morghab rivers being a distinct taxon but the work was never published and no material was available for the current book. Saadati (1977) referred to an unknown species of *Garra* from Baluchestan (CMNFI 2007-0035) here identified as *G. rossica*.

Zamani-Faradonbe *et al*. (2019) examined the phenotypic diversity of 113 fish from four rivers in four basins for 12 meristic and 19 morphometric traits. The rivers were the Firuzabad in Bushehr (presumably another species as *G. rossica* does not occur this far west according to me), the Sarbaz in the Makran basin, the Nehbandan in Sistan and the Torogh in the Hari River basin. The populations differed significantly in 10 meristic and 15 morphometric traits (later given as 11 and 13) such as shape and size of the head, body height (presumably depth), length of the caudal peduncle, and position of the dorsal fin. These differences were attributed to genetic isolation and differing environments.

**Key characters.** The single pair of small maxillary barbels (sometimes an anterior pair), absence of a free anterior margin to a weakly developed adhesive disc on the lower head surface, gill raker count, and distribution distinguishes this species. It is separated from the

closely related, but geographically separated, *G. variabilis* by smaller size, head length longer than caudal peduncle length, head length equal to or longer than pectoral fin length, distinctly emarginate caudal fin, and dorsal fin origin mid-way between snout tip and caudal fin base or closer to caudal fin base (Berg (1949) but see below, this last an individually variable character). *Garra rossica* is distinguished from all other species of *Garra* in Iran except *G. nudiventris* by having a weakly-developed mental disc (versus well-developed), one or two short barbels (versus two large), and low total gill rakers (10-16 versus 17-24). It is distinguished from *G. nudiventris* by having the predorsal mid-line region and belly fully covered by scales (versus naked) (Esmaeili *et al*., 2016).

**Morphology.** The body is elongated, moderately compressed laterally, and more compressed in the region of the caudal peduncle. The dorsal head profile rises gently, flat or slightly convex, more or less continuous with the dorsal body profile to the nape. The ventral profile is more or less straight to the anal fin origin. The head is moderately large and depressed, with a flat or slightly convex interorbital distance, the height at the nape is less than the head length, and the width at the nape is greater or about equal to the depth at the nape. The eye is placed dorso-laterally, slightly in the anterior half of the head. The anterior pair of barbels is usually absent but may be present and minute or even moderately well-developed, apparently independent of size (CMNFI 1979-0315). The disc is weakly developed with free lateral and posterior margins and slightly papillate. The disc is elliptical, slightly shorter than wide and narrower than head width through the base of the maxillary barbels. The rostral cap is developed, fimbriate, and papillate on the ventral surface. The upper jaw is almost or completely covered by the rostral cap. The dorsal fin has a distal margin straight or in some specimens slightly concave, the origin is slightly closer to the snout tip than to the caudal fin base, the origin is anterior to the vertical from the pelvic fin origin, the first branched ray is the longest, and the tip of the last branched ray reaches to a level with a vertical from the anus. The caudal fin is forked and the tips of the lobes are pointed. The anal fin is short, the first branched ray is the longest, the distal margin is straight or slightly concave, and the origin is closer to the pelvic fin origin than to the caudal fin base. The pelvic fin reaches back to the anus, with the origin closer to the anal fin origin than to the pectoral fin origin, and the origin lies below the second or third branched dorsal fin ray. The pectoral fin reaches back to a point 5-8 scales anterior to the pelvic fin origin, with length shorter than the head length.

Dorsal fin with 2-3 unbranched and 6-7, usually 7, branched rays, anal fin with 2-3 unbranched and 5 branched rays, pectoral fin branched rays 11-16, and pelvic fin branched rays 7-8. Scales on the flank are regularly arranged. Lateral line scales 33-46. Transverse scale rows above the lateral line are 5-6, and between the lateral line and the pelvic fin origin 4-5. Scales around the caudal peduncle number 15-18. Usually, there are 13-17 scales on the predorsal midline in front of the dorsal fin origin. The chest and midline of the belly are covered by embedded scales. One very short axillary scale is present at the base of the pelvic fin in some individuals, and there are 5-9 scales between the posteriormost pelvic fin base and the anus. The anus is 2-3 scales in front of the anal fin origin. The mid-line of the back, and the chest and belly are naked in some populations. Scales are a vertical ovoid with an anterior or subcentral anterior focus. The posterior scale margin is rounded and elongate, the dorsal and ventral margins are rounded and merge into the posterior margin, and the anterior margin has slight indentations above and below a shallow, rounded central protuberance. However, some scales may be squarish with rounded corners and scale shape can be very variable. Circuli are fine. Radii are found on all fields, moderate to very numerous although this is individually

variable. Esmaeili *et al*. (2010, 2012) detailed scale structure using scanning electron microscopy. Gill rakers on the lower arm number 9-11, 10-12 total in literature (but see below where 11-16), almost reaching the adjacent raker when appressed. Pharyngeal teeth are 2,4,5-5,4,2, 3,4,5-5,4,3, 2,4,5-5,4,3, 3,4,5-5,4,2, 2,4,5-5,3,2, 2,4,5-5,4,1, 2,4,4-4,4,2, 2,3,5-5,3,2 or 1,3,5-5,3,1. Zamani-Faradonbe and Keivany (2021b) reported 2,4,5-5,4,2 in fish from the Ladiz River and 3,5,6-6,5,3 in fish from the Nahang River, both rivers in the Hamun-e Mashkid basin. Teeth are conical to flattened, with an oblique but flattened crown which is slightly concave. Rarely crowns are blade-like and lack the flattened crown. The gut is very elongate and coiled. Total vertebrae number 34-36. Zamani-Faradonbe and Keivany (2021b) gave a range of 31-35 vertebrae, generally lower than that recorded by me and generally higher if four Weberian vertbrae are added to the count to accommodate the lower counts.

Saemi-Komsari et al. (2020) described the osteology of this species based on fish from the Hamun-e Mashkid basin finding differences with related and other species of cyprinoids in Iran. The vertebral count was given as 29, presumably excluding four Weberian vertebrae and possibly the hypural plate. Zamani-Faradonbe and Keivany (2021b) also described the osteology of fish from the Hamun-e Mashkid basin (Ladiz River), finding differences with *G. persica* and *G. typhlops* and even with *G. rossica* from the Nahang River.

Meristic values for Iranian specimens are:- dorsal fin branched rays 6(5) or 7(54), anal fin branched rays 5(59), pectoral fin branched rays 11(2), 12(14), 13(14), 14(15), 15(8) or 16(4), pelvic fin branched rays 7(39) or 8(14), lateral line scales 34(3), 35(6), 36(17), 37(10), 38(4), 39(7), 40(1), 41(-), 42(-), 43(1), 44(1), 45(1) or 46(1), total gill rakers 11(7), 12(18), 13(18), 14(9), 15(3) or 16(2), pharyngeal teeth 2,4,5-5,4,2 (15), 2,4,5-5,3,2(2), 2,4,5-5,4,1(1), 3,4,5-5,4,2(1) or 2,4,5-5,4,3(1), and total vertebrae 34(11), 35(37) or 36(11).

**Sexual dimorphism.** Males in spawning condition bear small but evident tubercles on the operculum and the head above the operculum, fine tubercles on top of and anteriorly on the head, small tubercles on the pectoral fin rays following the branching of the rays and on the first unbranched ray, and there are a few minute tubercles on anterior flank scales (CMNFI 1979-0236, 10 May 1977, but fish as early as 2 December 1977 (1979-0316) are tuberculate).

**Colour.** The upper flanks and back are dark to greyish-brown or greyish-black, greenish-brown or golden-brown and there may be large to small spots on the upper flanks. The body is silvery or brownish overall. The lower head and flank and the belly are white, yellowish-white or silvery. The belly and lower head may be bright yellow as are the neighbouring fin bases. There is often a dark bar at the base of the tail. Fins may be colourless. The bases of dorsal fin branched rays 3-5, and sometimes 6, have small dark spots. Fins can be quite dark, as dark as the adjacent body. Young have a bluish mid-lateral stripe along the flank. The peritoneum is black. Colour is darker in clear than in muddy water.

**Size.** Reaches 10.5 cm total length (Zamani-Faradonbe *et al*., 2018).

**Distribution.** This species is found in the Mashkel (= Mashkid) River basin of Pakistan, the Tedzhen (= Hari) and Murgab River drainages of the former U.S.S.R., and the Bejestan, Dasht-e Kavir, Dasht-e Lut, Hamun-e Jaz Murian, Hamun-e Mashkid, Hari River, Makran and Sistan basins of Iran. It is widespread in small streams, qanats and springs not all listed here (see **Sources** and references below), some of which are difficult to assign to a particular basin. Esmaeili *et al*. (2016) stated that its distribution overlaps with *G. nudiventris* so some records here may be of that species. In the Bejestan basin it is found in the Kalshur and Kharaji rivers and the Khiaban Qanat at Taibad; in the Dasht-e Kavir after Jouladeh-Roudbar *et al*. (2020); in the Dasht-e Lut basin in the Dehpabid, Eskelabad and Kardeh rivers,

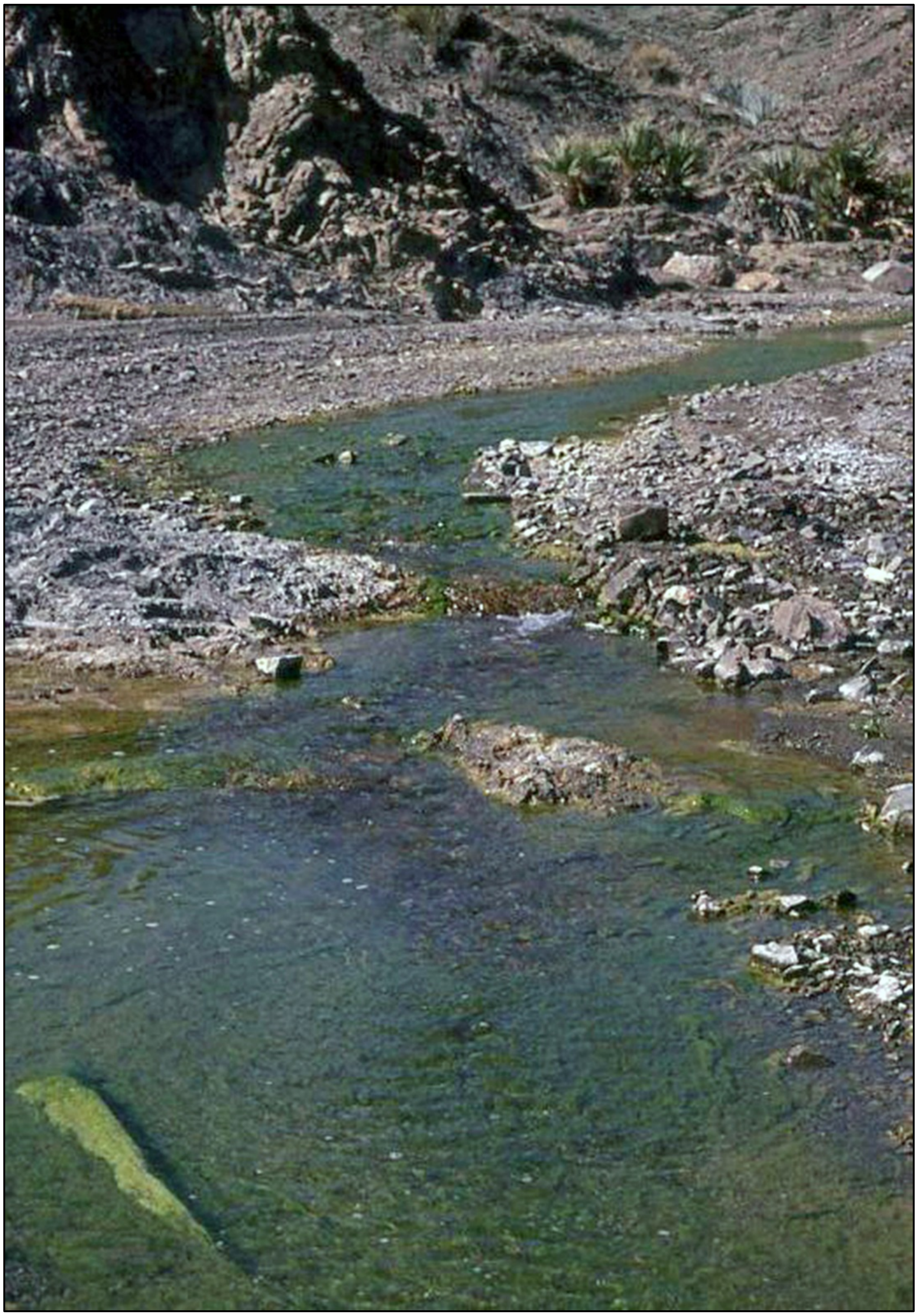
the Taebi Qanat near Birjand, and at Deh Salm; in the Hamun-e Jaz Murian in the Bampur. Irandegan, Kahiri, Karvandar and Ughin rivers; in the Hamun-e Mashkid in the Khanzaman, Ladiz, Nahang and Tahlab rivers, and in the Jalegh Qanat; in the Hari River basin in the Aal, Bakharz, Hari, Kardeh, Kashaf and Torogh rivers, Golbahar Spring and Kardeh Dam; in the Makran basin in the Geh, Sarbaz and Shakim rivers; and in the Sistan basin in the Hamun-e Farah and Hamun-e Puzak and at Nehbandan and Salabad (= probably Salehabad) (Nikol'skii, 1900; Berg, 1905; Berg, 1949; Menon, 1964; Spillman, 1972; Mirza, 1992; Abdoli, 2000; Moshkani and Pourkasmani, 2004; Esmaeili *et al*., 2012, 2016; Malekzehi *et al*., 2014; Khammar and Karamzahi, 2015; Jouladeh-Roudbar *et al*., 2015; Abbasi *et al*., 2016; Mousavi-Sabet *et al*., 2018, 2019; Zamani-Faradonbe *et al*., 2019; Zamani-Faradonbe and Keivany, 2021b). Khammar and Karamzahi (2015) recorded a "Gara fish", presumably this species from Khash area of Baluchestan in the Bidaster (not located), Dehpabid and Eskelabad rivers, and these localities may be in the Dasht-e Lut basin although they terminate in local sumps.

Records of *Discognathus variabilis* Heckel, 1843 from Sistan by Nikol'skii (1899) and Regan (1906) are *G. rossica* (Menon, 1964). Records from the Helmand and Koshk rivers, Afghanistan identified by Günther (1889) as *Discognathus lamta* (Hamilton, 1822) are also *G. rossica*. Zamani-Faradonbe *et al*. (2019) listed this species from the Firouzabad (= Firuzabad) River in Bushehr (presumably another species as *G. rossica* does not occur this far west according to me).

**Zoogeography.** See under *Garra persica* and also under the genus. *G. rossica* is related to *Garra variabilis* of the Tigris-Euphrates basin.

**Habitat.** This species is found in rivers, streams, springs, jubes (= irrigation ditches), lakes, ponds, marshes, channels in reed beds and qanats. In Sistan, it is reported from pools, slow-flowing ditches, channels and in reed beds. In Pakistan, it prefers high altitudes, a high-water temperature and rocky and gravelly river beds (Rafique, 2007). Collection data included a temperature range of 15-31ºC, pH 6.2-8.1, conductivity 0.53-4.9 mS, river width 10 cm to 100 m, still to fast current, depth 20-100 cm, clear and colourless or muddy water, detritus, mud, sand, gravel, pebble, stone, bedrock or concrete bottoms, encrusting, submergent filamentous algae and brown slime, emergent reeds and rushes and floating vegetation, and a grassy shore.

Habitat of *Garra rossica* (and *Garra persica* and *Cyprinion watsoni*),
CMNFI 1979-0315, Baluchestan, Bampur River north of Karvandar,
1 December 1977, Brian W. Coad.



Habitat of *Garra rossica* (and *Cyprinion watsoni*), CMNFI 1979-0316, Baluchestan, stream in Sarbaz River drainage, 2 December 1977, Brian W. Coad.

Habitat of *Garra rossica*, Baluchestan, Irandegan River, Hamid Reza Esmaeili.

**Age and growth.** Sexual maturity is attained at 2-3 years. Females grow more rapidly than males. Nowferesti *et al*. (2014) found a *b* value of 3.19 for 49 fish, 3.0-6.6 cm total length, from Bakharz, Razavi Khorasan. Zamani-Faradonbe *et al*. (2018) found a *b* value of 2.7 for 151 fish, 3.1-10.5 cm total length, from Iran. Abbasi *et al*. (2019) gave a *b* value of 3.022 for 68 fish, 2.45-9.4 cm total length, from the Kardeh River.

**Food.** Gut contents include green filamentous algae, higher plant fragments and sand grains.

**Reproduction.** Spawning occurred in the summer and up to 984 eggs were produced. Some fish still contained undeposited eggs in late July. Egg diameter was up to 1.06 mm (Nikol'skii, 1945). On 2 December 1977 (CMNFI 1979-0316) eggs were 1.3 mm. On 8 May 1977 (CMNFI 1979-0227) eggs were 1.2 mm suggesting either early spawning or prolonged retention of eggs. The most tuberculate males were found in both November and May.

**Parasites and predators.** None reported from Iran although large, abdominal helminths were noted in fish from CMNFI 1979-0227.

**Economic importance.** This species is an aquarium fish (Abell *et al*., 2008) and is eaten in Baluchestan (Khammar and Karamzahi, 2015).

**Experimental studies.** Khammar and Karamzahi (2015) examined the heavy metals in tissues of Gara fish (presumably this species) in waters near Khash, Baluchestan and found zinc had the highest accumulated level with lead and nickel the lowest and copper intermediate. The fish were safely permissible for human consumption.

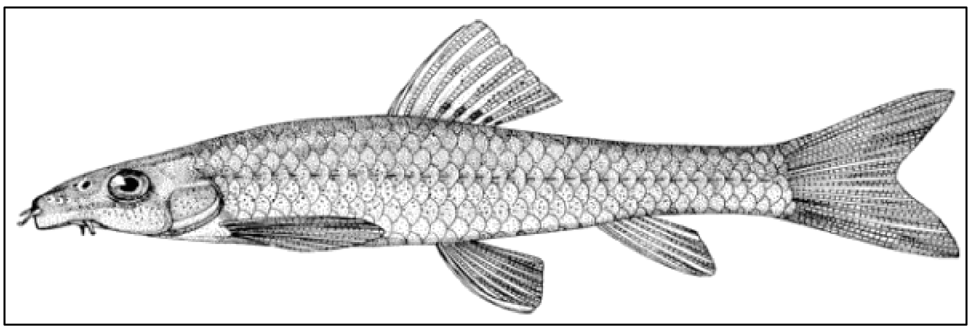
**Conservation.** This species is widely distributed in eastern Iran and does not appear to be under significant threat. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern because of its presence in many localities and high population numbers.

**Sources.** Type material:- *Discognathus rossicus* (ZISP 10365).

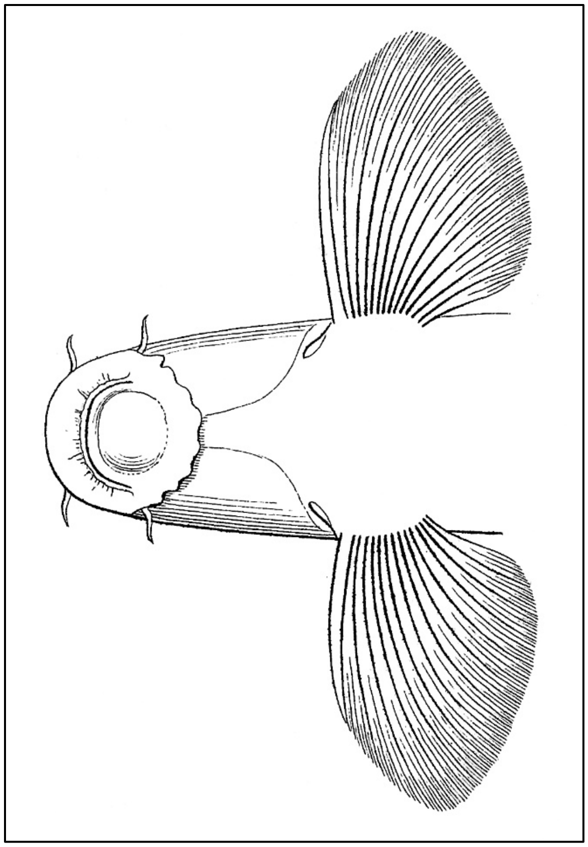
Iranian material:- CMNFI 1979-0226, 5, 37.2-49.0 mm standard length, Sistan, pool

near Kuh-e Khajeh (30º57'N, 61º17'E); CMNFI 1979-0227, 6, 48.1-61.1 mm standard length, Sistan, neizar at Kuh-e Khajeh (30º57'N, 61º16'E); CMNFI 1979-0230, 2, 29.2-43.4 mm standard length, Sistan, Hamun-e Puzak (ca. 31º15'N, ca. 61º42'E); CMNFI 1979-0236, 7, 18.3-47.3 mm standard length, Sistan, ditch 27 km from Zabol (ca. 30º52'N, ca. 61º22'E); CMNFI 1979-0238, 11, 15.3-29.2 mm standard length, Sistan, ditch 11 km south of Zabol (30º57'N, 61º27'30"E); CMNFI 1979-0315, 2, 24.9-50.3 mm standard length, Baluchestan, Bampur River 2 km north of Karvandar (27º51'N, 60º46'E); CMNFI 1979-0316, 9, 35.7-53.4 mm standard length, Baluchestan, stream in Sarbaz River drainage (26º48'N, 61º02'E); CMNFI 1979-0330, 68, 14.7-65.1 mm standard length, Baluchestan, stream 22 km west of Qaleh-ye Zaboli (27º02'30"N, 61º26'E); CMNFI 1979-0336, 30, 22.4-31.6 mm standard length, Baluchestan, qanat 7 km from Khash (28º10'N, 61º15'E); CMNFI 1979-0339, 3, 40.6-51.0 mm standard length, Baluchestan, Tahlab River drainage 16 km from Mirjaveh (28º56'30"N, 61º21'E); CMNFI 2007-0031, 2, 36.0-45.5 mm standard length, Baluchestan, headwater of Bampur River (27º51'N, 60º46'E); CMNFI 2007-0035, 9, 28.9-50.1 mm standard length, Baluchestan, stream west of Zaboli (ca. 26º58'N, ca. 61º27'E); USNM 205905, 6, 30.2-36.9 mm standard length, Baluchestan, small springs in upper Sarbaz River basin (no other locality data).

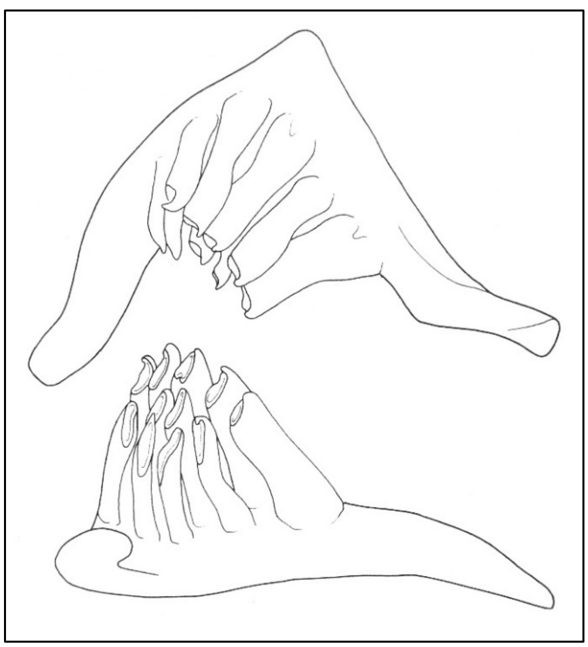
## ***Garra rufa***
(Heckel, 1843)



*Garra rufa*
Susan Laurie-Bourque @ Canadian Museum of Nature.

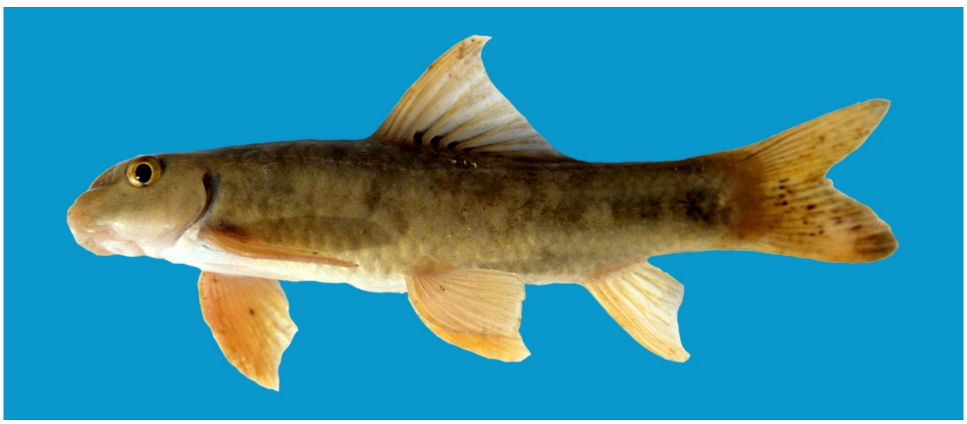


*Garra rufa*, ventral head, after Heckel (1843b).



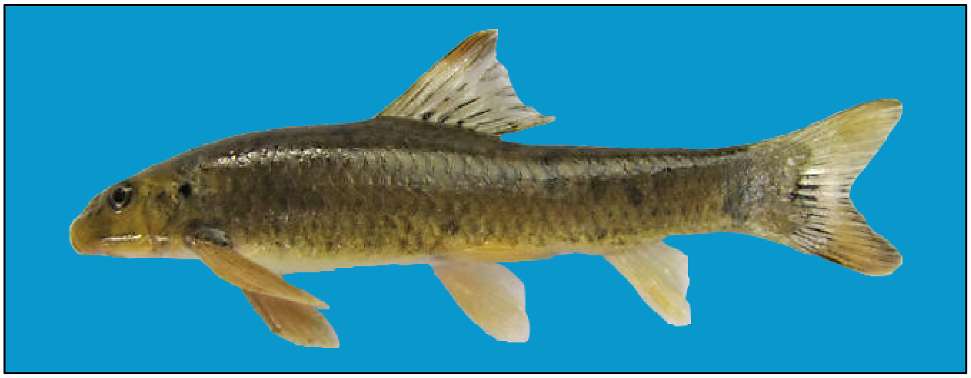
*Garra rufa*, pharyngeal teeth, Freidhelm Krupp.

*Garra rufa*, CMNFI 2008-0163, Khuzestan, Marun River near Behbehan,
21 November 2000, Brian W. Coad.



*Garra rufa*, CMNFI 2008-0163, Khuzestan, Marun River near Behbehan,
21 November 2000, Brian W. Coad.

*Garra rufa*, CMNFI 2008-0167, Khuzestan, stream above Diuni Darreh,
26 November 2000, Brian W. Coad.

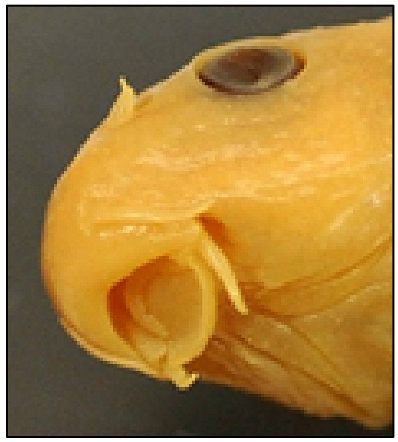


*Garra rufa*, Chahar Mahall and Bakhtiari, Bazoft River, Karun River basin, August 2009, Keyvan Abbasi.

*Garra rufa*, Iran, Persis basin, Hamid Reza Esmaeili.

*Garra rufa*, Fars, Shapur River, Azad Teimori.

*Garra rufa*, 62.9 mm standard length, CMNFI 1979-0113, Fars, Sa`di's Tomb in Shiraz, 23 June 1976, Brian W. Coad.



*Garra rufa*, ventral head, as above, Brian W. Coad.

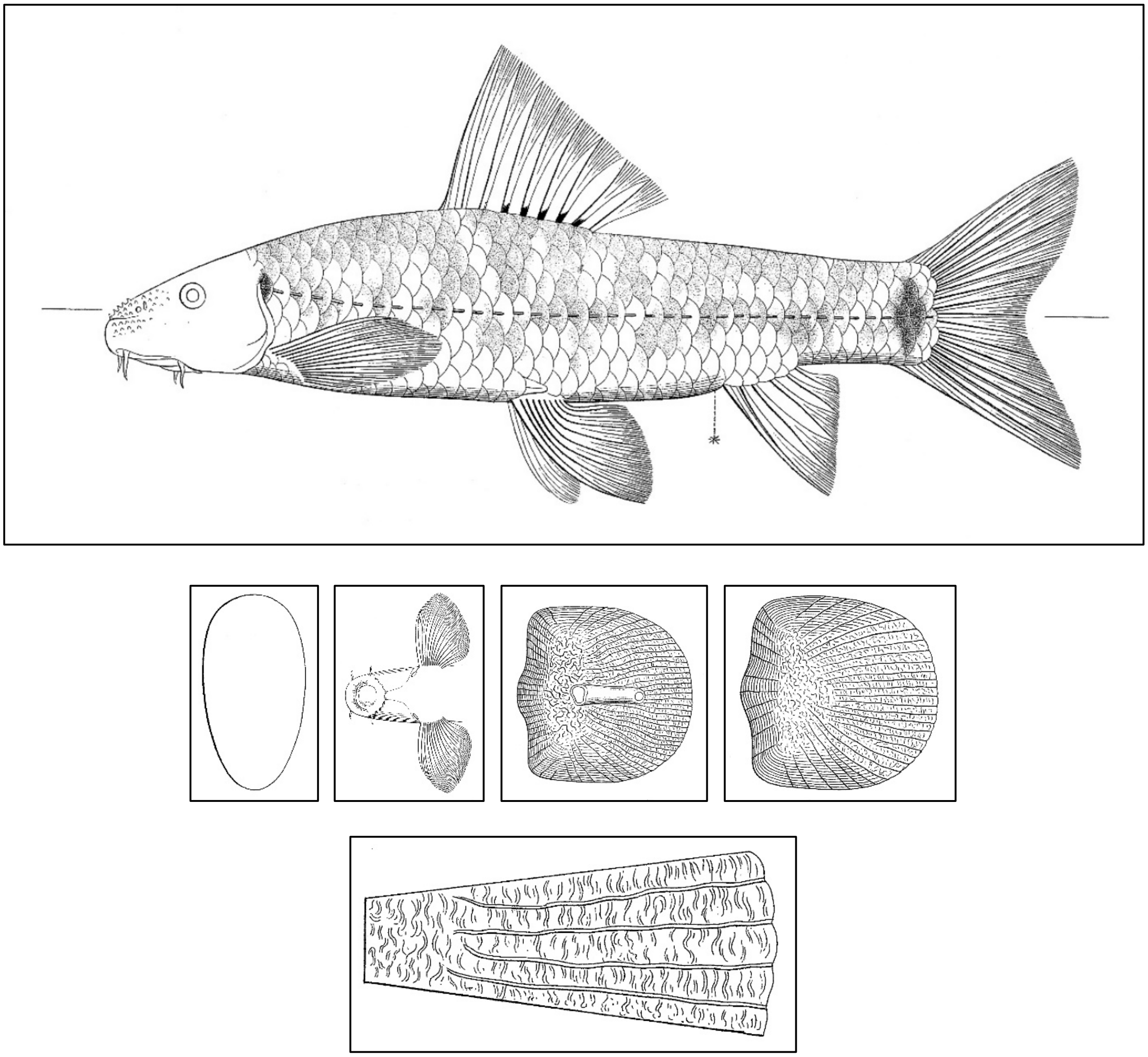
**Common names.** Mahi-ye sangi (= rock or stone fish), mahi-ye sang lis (= slippery rock fish), mahi-ye sanglis khermez (= slippery rock fish ?), gararufa or gara, gel khorok or gel khorak (= mud-eater), gel-e cheragh (= mud-eater or mud-grazer), gel ra, shirbot.

[Djulake (or julaka, from the Kurdish meaning Jewish), kokur ahmar or karkoor ahmar (or karkur al-hamrah, perhaps relate to k-r-k-r meaning to giggle, hence giggling fish, and hamrah meaning red-coloured) (all previous from Mikaili and Shayegh (2001)); garagoor; gassur achmar (meaning red gassur) or gassur hadjari (gassur of the pilgrims) at Aleppo (= Haleb, Syria) according to Heckel (1843b), all in Arabic; Gurik, Herver and Yağlı balık or Yağlı balığı (local names in eastern Turkey) (Kaya *et al*., 2016; Çiçek *et al*., 2020); common garra, kangal fish, little dermatologist, doctor fish, nibble fish, red garra, red stone lapper, reddish log sucker, stone fish].

**Systematics.** *Discognathus obtusus* Heckel, 1843 described from "Aleppo" and "Mossul", *Discognathus crenulatus* Heckel, 1847 described from the "Confluenten des Araxes, als aus den Quellen des Saadi und dem Kara-Agatsch" (= probably includes the Pulvar River near Persepolis; Sa`di at 29°37'N, 52°35'E, now within the city of Shiraz; and the Qarah Aqaj River; all in Fars) are synonyms. Records of *Garra lamta* (Hamilton, 1822) from Iran are in error (Menon, 1964).

The types of *Discognathus rufus* are from "Aleppo" according to Heckel (1843b) and the syntypes are, according to Krupp (1985c), in the Naturhistorisches Museum Wien under NMW 53240, eight specimens, 59-108 mm standard length from Aleppo and one syntype is in the Senckenberg Museum Frankfurt under SMF 553 (formerly NMW), 103 mm standard

length and also from Aleppo. The catalogue in Vienna listed six specimens. One specimen from NMW 53240, 112.3 mm standard length (as measured by me), was designated as the lectotype and seven fish, 60.2-97.5 mm standard length as paralectotypes by F. Krupp, 29 October 1984, and published in Krupp and Schneider (1989).

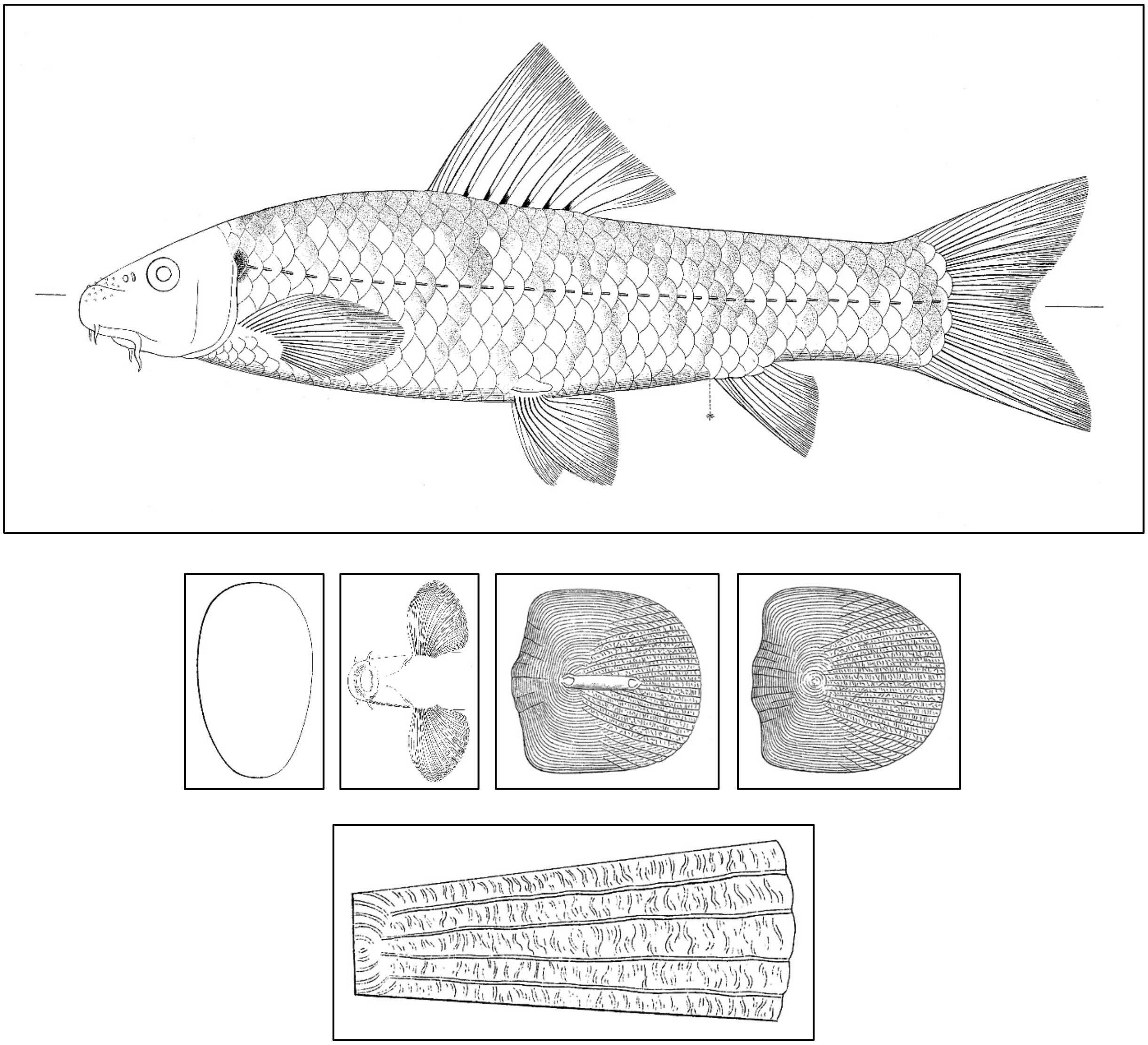


*Discognathus rufus*,
body, cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Discognathus rufus*, lectotype and paralectotypes, NMW 53240,
Naturhistorisches Museum, Wien.


*Discognathus rufus*, lectotype and paralectotypes, NMW 53240,
Naturhistorisches Museum, Wien.

Four syntypes of *Discognathus obtusus*, 46-134 mm standard length, are under NMW 53238 and two syntypes, 65-92 mm standard length, are under SMF 5408 (formerly NMW and also numbered SMF 447) (65.1-93.1 mm standard length). A further 10 fish under NMW 53257 and measuring 31.5-106.2 mm standard length are also indicated on the jar in Vienna as syntypes but this is probably in error as the catalogue listed six fish. Eschmeyer *et al*. (1996) gave only one syntype under NMW 53257 (but the *Catalog of Fishes*, downloaded 15 May 2018, gives all 10 as syntypes), as well as four syntypes under NMW 53238, one dried syntype under NMW 79372, one syntype in the Senckenberg Museum Frankfurt under SMF 447 and two syntypes under SMF 5408 (formerly NMW).



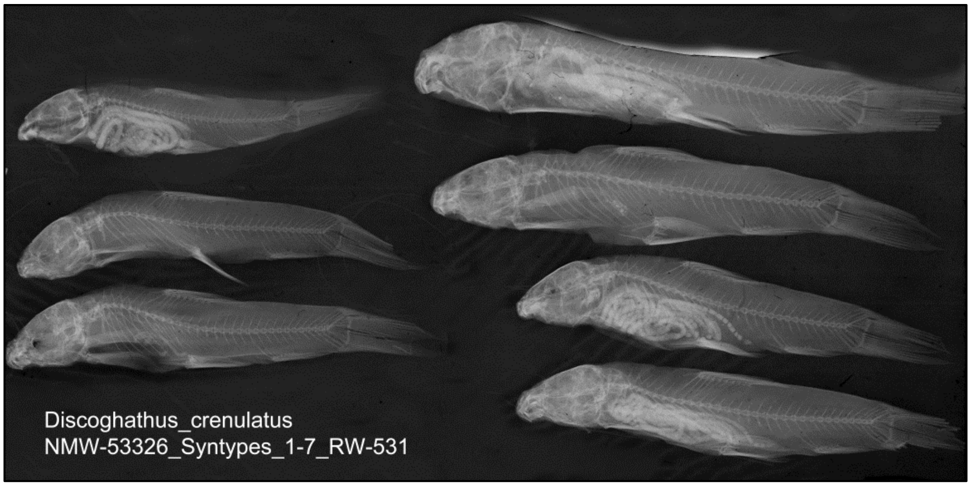
*Discognathus obtusus,*
body, cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Discognathus obtusus*, syntypes, NMW 53238, Naturhistorisches Museum, Wien.


*Discognathus obtusus*, syntypes, NMW 53238, Naturhistorisches Museum, Wien
(label at top right is incorrect).

The syntypes of *Discognathus crenulatus* are in the Naturhistorisches Museum Wien under NMW 53236 (14 specimens) from the Qarah Aqaj River and 53237 (6) from Sa`di measuring 33-79 mm standard length (Kähsbauer, 1964). The 14 specimens under NMW 53236 measure 24.0-75.9 mm standard length and seven (not six) specimens under NMW 53237 measure 35.4-56.6 mm standard length according to my observations. Neither the record of Kähsbauer (1964) nor my own data from jars on the shelves accord with the catalogue in Vienna which gives 10 or 8 and 6 or 5 specimens respectively for these two syntype localities.

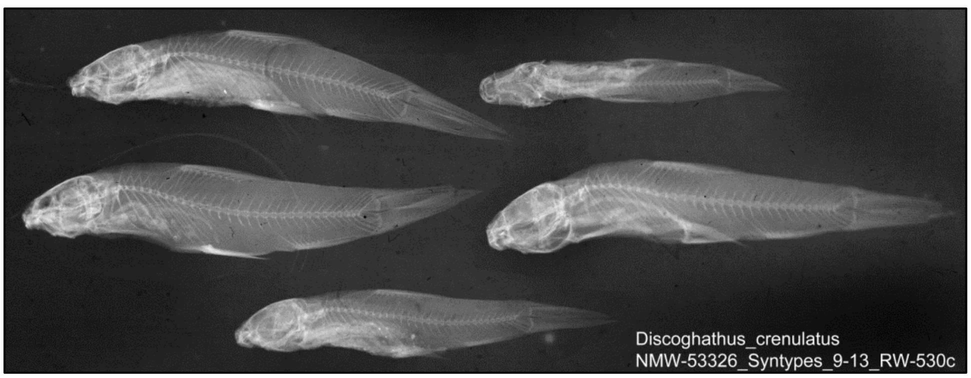

*Discognathus crenulatus*, syntypes, NMW 53236, Naturhistorisches Museum, Wien.




*Discognathus crenulatus*, syntypes, NMW 53236, Naturhistorisches Museum, Wien (note number on x-ray appears to be incorrect).


*Discognathus crenulatus*, syntypes, NMW 53236, Naturhistorisches Museum, Wien (note number on x-ray appears to be incorrect).

*Discognathus crenulatus*, syntypes, NMW 53236, Naturhistorisches Museum, Wien.




*Discognathus crenulatus*, syntypes, NMW 53236, Naturhistorisches Museum, Wien (note number on x-ray appears to be incorrect).

Bianco and Banarescu (1982) referred their material from the Hablehrud (= Hableh River) and Mond River to *Garra rufa crenulata* as these fish had fewer scales (29-32 for Mond and 33-34 for Hablehrud versus 35-38 from the Tigris-Euphrates) and fewer gill rakers (15-21 versus 25-27 in Tigris-Euphrates specimens). Possible syntypes of *crenulata* had intermediate scale counts (31-34) between Mond and Hablehrud fish. These authors suggested that there may be distinct subspecies in these two rivers. Their sample sizes are too small in my opinion to warrant subspecies recognition. Berg (1949) was uncertain of the status of this taxon.

A principal components analysis on 448 fish from the Hormuz, Lake Maharlu, Persis and Tigris River basins and Sa`di's Tomb using 20 morphometric and five meristic characters did not separate any of these groups. Note that fish from the Hormuz basin, rivers draining to the Straits of Hormuz, modally had 7 dorsal fin branched rays (as in *G. persica*) but branched caudal fin rays were modally 17 (not 16 as in *G. persica*). There may be some introgression in this region of Iran or these fish are a distinct taxon (see *Garra* sp. below). Ghalenoei *et al*. (2010) examined fish from 13 stations in the Tigris and Persian Gulf (Persis) basins and found the Mond River population was separated from the rest, which overlapped each other. Keivany *et al*. (2015) examined 485 fish from 29 populations in six river systems using 28 morphometric and 10 meristic characters but was unable to distinguish the populations. Many characters differed significantly although ranges overlapped.

Menon (1964) and Karaman (1971) considered *Garra persica* to be a synonym but this species is regarded here as distinct. Both these authors referred specimens from the Tigris River basin of Iran (and therefore all Iranian specimens) to a subspecies, *Garra rufa obtusa*, distinguished from the type subspecies in Syria, Lebanon, Israel and Jordan by having a variable number of dorsal fin branched rays (7-8), the anal aperture further forward, and the anal fin origin half way between the pelvic fin base and the caudal fin base as opposed to closer to the pelvic base. Krupp (1985c) synonymised *Garra rufa obtusa* with the type subspecies as did Hamidan *et al*. (2014).

Nezameslami *et al*. (2013) examined fish from nine stations in the Karkheh River basin morphometrically finding that the Chardavol River population was separable. Shabani *et al*. (2013) used six microsatellite markers when investigating fish from the Gamasiab, Sepidbarg (= Sefid Barg) and Dalaki rivers, finding that the Sepidbarg (Kermanshah) and Dalaki (Bushehr) populations formed a cluster separate from the Gamasiab (Kermanshah) population. Askari *et al*. (2014) studied fish from the Shapur River, Fars in spring and fall samples finding both morphometric (11 in males, 19 in females) and meristic (1 in males and 2 in females) characters were seasonally different. Askari *et al*. (2014) used six microsatellite locations to study genetic diversity in the Fahlian and Sarab-e Bahram rivers of Fars Province, finding low separation between the two populations because of high gene flow and acceptable genetic diversity. Kolangi Miandare (2016) examined 240 fish from six populations in the Tigris River basin of Iran (*sic*, actually the Persis basin) using eight microsatellite loci, finding a fairly high level of genetic variation but little difference between populations, and the majority of migration occurred between populations located about 30 km from each other. Vesaghi *et al*. (2016) were able to separate fish from eight sample stations in the Dinawar River, Kermanshah based on morphometric and meristic characters. Pourshabanan *et al*. (2017) examined 36 fish from the Beshar River and found high overlap with fish from other localities. Askari *et al*. (2017) used microsatellite markers to investigate the genetic diversity of 56 fish from the Beshar and Kabgiyan rivers of Kohgiluyeh and Bowyer Ahmad Province (identified as *G. persica* but presumably *G. rufa*). Allelic diversity and genetic variation were favourable, genetic variation between populations was low and most variation was within populations. Zamani-Faradonbe *et al*. (2020) examined 55 fish from the Jarrahi River in the Aghajari, Behbahan and Rostam Abad tributaries for 10 meristic and 19 morphometric characters and geometric morphological information was extracted using 13 landmark points. Differences were found between the three populations in meristic (lateral line scales, predorsal scales, caudal peduncle scales) and morphometric (14 of 19 characters) traits. In the geometric morphometric analysis, the major part of the shape variation was due to landmark points in the head region and the dorsal fin base, with the anal fin and caudal peduncle being the most conservative body regions. The populations had significant differences in body shape with populations from Aghajari and Behbahan tributaries being most similar and the Rostam Abad population different from the two other population. Abbasi *et al*. (2020) examined 98 specimens from the Aran, Dinvar and Gamasiab rivers (Karkheh River drainage) and the Armand and Bazoft and rivers (Karun River drainage) for 33 morphometric and nine meristic traits. The results showed significant differences among the studied populations in all morphometric data except postdorsal, preanal and postorbital lengths, and differences in lateral and lower line scales and upper and lower gill rakers in meristic data. The morphometric data was better than meristic data in expressing the differences among the studied populations.

Mansouri Khajeh Langi *et al*. (2017) examined scale shape in order to distinguish fish

from 10 rivers in Iran but most measurements showed overlap and the populations could not be separated robustly.

Saemi-Komsari *et al*. (2021) compared 60 fish from the Persian Gulf (= Persis) and Hormuz basins for 14 morphometric traits and found significant differences related to the dorsal fin length, pectoral fin length, body depth and eye diameter, attributed to habitat.

Cicek *et al*. (2016) compared fish from seven localities in the Tigris River system of southeast Turkey. The success rate of classifying groups using meristic characters was 56.32% and for morphometric characters 56.7%. However, sample sizes were as low as two and four fish.

Fish lacking scales on the breast were named by Berg (1949) as *Garra rufa gymnothorax*. Molecular analyses separate a taxon considered to be this distinct species, *Garra gymnothorax*, from *G. rufa* in Iran (see above), but this is a variable character and populations of *Garra rufa* in Turkey have a naked breast (J. Freyhof, in litt., 23 April 2016). My material from Iran is referred here to *Garra rufa* until more definitive anatomical characters (or extensive molecular surveys of populations) can be carried out. Many of these Iranian *G. rufa* samples appear to lack breast scales (variably developed, obscured by skin and mucus) but occasional samples are fully scaled, e.g., CMNFI 2008-0102, see below.

Saadati (1977) referred to an unknown species of *Garra* from Fars (CMNFI 2007-0063) here identified as *G. rufa*.

**Key characters.** This species is distinguished by having two pairs of barbels, the adhesive disc is well-developed with a free anterior margin, the dorsal fin has 8 branched rays modally, and the caudal fin 17 branched rays modally. It is separated from the related *G. gymnothorax* generally by the breast being fully covered by scales or embedded in some populations (versus naked) (but see above and under *G. gymnothorax*).

**Morphology.** The body is elongated, moderately compressed laterally, and more compressed in the region of the caudal peduncle. Some fish are very rounded in cross section while others are more terete, possibly related to habitat as observed in other cyprinoid fishes. The dorsal head profile rises gently, flat or slightly convex, and more or less continuous with the dorsal body profile to the nape or about the middle between the nape and the dorsal fin origin. The ventral profile is more or less straight to the anal fin origin. The head is moderately large and depressed, with a slightly convex or flat interorbital distance. The depth at the nape is less than head length and width at the nape is greater, or about equal to, depth at the nape. The eye is placed dorso-laterally partly in the posterior half of the head. Barbels are in two pairs, the rostral barbel antero-laterally located, is shorter or about equal to the eye diameter, and the maxillary barbel at the corner of the mouth is shorter than the rostral barbel. The well-developed disc has free lateral and posterior margins and is heavily papillated with batteries of fleshy papillae arrayed around the periphery of the whole disc. The centre of the disc can be papillate also or free of papillae. The disc is often elliptical, shorter than wide, and narrower than the head width through the base of the maxillary barbels. The disc, however, can vary from almost circular, to squarish to sub-rectangular in an antero-posterior direction. The posterior margin of the disc may be a smooth curve, indented slightly at a few places or markedly indented so as to form up to four lobes. The rostral cap is well-developed and fimbriate, and papillate on the ventral surface. The upper lip is present as a thin band of papillae arranged in two ridges. The upper jaw is almost or completely covered by the rostral cap. The dorsal fin distal margin is concave, the fin origin is closer to the snout tip than to the caudal fin base, the fin origin is anterior to the vertical from the pelvic fin origin, the first

branched ray is the longest, and the tip of the last branched ray reaches the vertical from the anus. The caudal fin is forked with lobe tips pointed. The anal fin is short, with the first branched ray the longest. The distal margin is straight or slightly concave, and the origin is closer to the pelvic fin origin than to the caudal fin base. The pelvic fin reaches back to the anus, its origin is closer to the anal fin origin than to the pectoral fin origin, and its origin is below the second or third branched dorsal fin ray. The pectoral fin reaches back to a point 4-5 scales anterior to the pelvic fin origin and its length is shorter or almost equal to the head length. The above is based partly on Esmaeili *et al*. (2019).

Dorsal fin with 2-3, usually 3, unbranched and 7-9 branched rays with a very strong mode at 8, anal fin with 2-3 unbranched and 3-6 with a very strong mode at 5 branched rays (99.6% of 534 specimens from Iran). Pectoral fin branched rays 11-15 (in literature, but see table), and pelvic fin branched rays 7-9 (but see table). Lateral line scales 25-41, scales from the dorsal fin origin to the lateral line 3-6, from the lateral line to the pelvic fin origin 2-5, predorsal mid-line scales 9-14, and scales around the caudal peduncle 12-19 with a strong mode at 16. Scales extend obviously onto the basal rays of the caudal fin. Scales on the flank are regularly arranged. The chest has embedded scales and the belly is covered by scales. There is one short axillary scale at the base of the pelvic fin in some individuals, and 4-7 scales between the posteriormost pelvic fin base and the anus. The anus is 3-4 scales in front of anal fin origin. Scales have parallel sides and an almost vertical anterior margin and so appear squarish anteriorly. The anterior margin is wavy, indented dorsally and ventrally just next to the posterior sharp corners. The posterior margin of the scale is rounded with rounded corners. The focus is subcentral anterior, there are numerous fine circuli, numerous posterior radii and a few anterior radii, as few as five in a fish 125.5 mm standard length (CMNFI 2008-0120). Radii may extend into the lateral fields. Zareian and Esmaeili (2015) observed abnormal scales such as fusions, two foci and lateral line deformations. Yedier *et al*. (2016) gave details of scale and otolith morphologies for fish from the hot spring at Sivaş in Turkey. Pharyngeal tooth formula 2,4,5-5,4,2 or 2,4,4-4,4,2 (3,3,5-5,3,3 in Heckel (1843b)). Teeth are hooked at the tip. The short gill rakers number 16-24 in total, 12-17 on the lower arm in the literature. In Iranian specimens the range is 14-34 (a range only is given since rakers are difficult to count on the arch ends with accuracy and the number may be related to age). Total vertebrae in Iranian specimens number 32-37 (see table, and note that Keivany *et al*. (2015) gave 30-35). The syntypes of *D. rufus*, NMW 53240, have 34(1), 35(6) or 36(1) vertebrae. The syntypes of *D. crenulatus* (two omitted as faint), NMW 53326, have 33(2) or 34(11) vertebrae. The syntypes of *D. obtusus*, NMW 53238, have 35(2) or 36(2) vertebrae. The chromosome number is probably 2n = 52 (Klinkhardt *et al*., 1995) although Ünlü *et al*. (1997) gave 2n = 38 for Turkish specimens with 26 meta- to sub-metacentric chromosomes and 12 telo- to sub-telocentric chromosomes (NF = 64) and Ergene Gözükara and Çavaş (2004) gave 2n = 44 for Turkish specimens with 22 metacentric and 20 sub-metacentric chromosomes and two acrocentric ones (NF = 85). Esmaeili and Piravar (2007) examined fish from the Rodbal (= Rudbar) River in Fars and found 2n = 50 with arm number NF = 84 and the karyotype formula of 10 metacentric, 24 sub-metacentric and 16 sub-telocentric chromosomes.

Teimori *et al*. (2011) gave micro-structure details of the adhesive disc which shows correlations with habitat characters. Abundant mucous cells in the epidermis of the disc give an oily appearance and, with the dorso-ventrally compressed snout, offer minimal resistance to water currents.

Zamani-Faradonbe *et al*. (2020) studied the osteological plasticity of populations

inhabiting 29 rivers in four basins in Iran. There were 12 differences in the head skeleton, four in jaw elements, three in the suspensorium, two in the opercular series, two in the circumorbital series, four in the hyoid arches, one in the branchial apparatus, three in the Weberian apparatus, three in the dorsal fin skeleton, one in the anal fin skeleton, one in the pectoral fin girdle, three in the ventral fin skeleton and two in the caudal fin skeleton. It was suggested these differences were evolutionary adaptations to new habitats.

Zareian *et al*. (2021) described scale abnormalities from fish in the Fahlian, Rodbal and Shapur rivers.

Meristic values for Iranian specimens are:-

| Basin/Dorsal fin branched rays | 7 | 8 | 9 | X | S.D. |
|---|---|---|---|---|---|
| Lake Maharlu | | 90 | 2 | 8.0 | 0.15 |
| Sa`di's Tomb | 5 | 20 | | 7.8 | 0.41 |
| Persis | 16 | 173 | 1 | 7.9 | 0.29 |
| Tigris River | 13 | 168 | 3 | 8.0 | 0.29 |

| Basin/Pectoral fin branched rays | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 18 | X | S.D. |
|---|---|---|---|---|---|---|---|---|---|---|
| Lake Maharlu | | 1 | 2 | 15 | 50 | 23 | 1 | | 14.1 | 0.78 |
| Sa`di's Tomb | | | 5 | 16 | 2 | 2 | | 1 | 13.2 | 1.24 |
| Persis | | 1 | 4 | 57 | 84 | 42 | 1 | | 13.9 | 0.81 |
| Tigris River | 1 | | 9 | 47 | 92 | 33 | 2 | | 13.8 | 0.86 |

| Basin/Pelvic fin branched rays | 6 | 7 | 8 | 9 | X | S.D. |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Lake Maharlu | | 8 | 84 | | 7.9 | 0.28 |
| Sa`di's Tomb | | 9 | 16 | | 7.9 | 0.27 |
| Persis | 1 | 109 | 79 | | 7.4 | 0.50 |
| Tigris River | 1 | 44 | 138 | 3 | 7.8 | 0.47 |

| Basin/ Lateral line scales | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 40 | x | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Maharlu | | | | | 1 | 4 | 13 | 21 | 32 | 30 | 9 | | | | | 31.2 | 1.54 |
| Sa`di's Tomb | | | | | | 2 | | 6 | 6 | 7 | 4 | | | | | 33.1 | 1.39 |
| Persis | 1 | 1 | 5 | 16 | 25 | 24 | 25 | 42 | 36 | 19 | 5 | | | | | 31.2 | 2.06 |
| Tigris River | | | | | | 2 | 2 | 19 | 39 | 59 | 45 | 9 | 2 | 1 | 1 | 33.5 | 1.33 |

| Basin/Total vertebrae | 32 | 33 | 34 | 35 | 36 | 37 | x | S.D. |
|---|---|---|---|---|---|---|---|---|
| Lake Maharlu | | 6 | 38 | 21 | 3 | | 34.3 | 0.70 |
| Sa`di's Tomb | | | 14 | 9 | | | 34.4 | 0.50 |
| Persis | 2 | 15 | 36 | 34 | 9 | | 34.3 | 0.93 |
| Tigris River | | 17 | 49 | 76 | 17 | 2 | 34.6 | 0.86 |

**Sexual dimorphism.** Large males become heavily tuberculate on the front and sides of the snout and in a band from the eye to the nostril and across to the other nostril and eye. A deep, tubercle-free groove is apparent between the upper band of tubercles through the nostrils

and the tubercles on the snout above the mouth. These bands of tubercles may be in defined patches between each eye and nostril, between the nostrils, antero-ventrally from each nostril to the anterior barbel, and centrally on the snout in a fish 125.5 mm standard length caught on 20 September 1995 (CMNFI 2008-0120). Some fish appear to be late spawners or retain tubercles for some time after spawning based on the above (and see below under **Reproduction**). Patches below the nostrils and on the anterior snout can run together and the upper row between the nostrils can be connected to the lower row in, for example, a 101.7 mm standard length fish caught on 9 July 1977 (CMNFI 1979-0289). Some fish have very fine tubercles dorsally on the head. Fins appear to lack tubercles, unusual in cyprinid fishes, if true.

**Colour.** Overall colour is brownish-olive to dark green with darkly-mottled flanks and a yellowish to whitish belly. The head and flanks may be a rusty-red, bronze or golden. A dark or bluish-green band runs along the whole flank ending in a spot on the caudal fin base. Much of the body may be blackish with only the belly creamy. Others are a light olive-green with lime-green highlights giving an iridescent effect especially on upper anterior flank scales. There is a black, greenish-blue, lime-green or dusky-blue spot behind the upper corner of the gill opening, sometimes extending as a bar to the pectoral fin base where the skin is also blue. Fins can be yellowish with darker margins. The pectoral fins can be orange-pink dorsally, grey-white or slightly orange-pink ventrally. The pelvic and anal fins may be orange with the fin rays yellow posteriorly in the anal fin but yellow mesially in the pelvic fin. The bases of the pectoral, pelvic and anal fins are orange-red in breeding males and the caudal fin is orange. The caudal fin can be orange to red ventrally and yellow dorsally. There is a black spot at the caudal fin base and the upper caudal lobe may have a few dark grey spots. The dorsal fin is dark green with reddish pigment at its middle. There is usually a dark spot at the bases of each of the middle 4-5 dorsal fin rays. In some specimens the dorsal fin is orange with yellow posterior rays. The pectoral, dorsal and caudal fin rays may be olive to black rather than yellow or orange. The iris is bright yellow, orange or red.

There is variation in colouration. Some fish are pale, even a sickly grey, while others are very dark; the spots on the dorsal fin may extend two-thirds of the way up the fin rather than being restricted to the base; and the flanks may not be mottled. Fish from muddy water are a sickly grey with the body mottled and the lower caudal lobe dark. Their colour darkens and becomes brighter after immersion in ice water. Fish from deep in qanats are very pale.

**Size.** Attains 24.0 cm total length in the Tigris River in Iraq (Rahemo, 1995), reaches 15.9 cm (Krupp, 1985c), and over 17.0 cm according to Heckel (1843b). Fish up to 18.5 cm total length are known from Khuzestan and 18.8 cm total length in the Dalaki River (Pazira *et al*., 2013).

**Distribution.** This species is found in the Tigris-Euphrates basin and the Ceyhan, Orontes (= Asi), Quwayq and Jordan river basins and coastal drainages of the eastern Mediterranean as well as much of southern and western Iran. In Iran it is found in the Hormuz, Kor River, Lake Maharlu, Persis and Tigris River basins. It is widely distributed in small streams, springs and qanats not all listed here (see **Sources** and literature below). In the Hormuz basin in the Axe Rostam, Kul, Mazaii and Shur rivers, Iloud Spring and Rudan County generally (but these all probably need confirmation); in the Kor River basin in the Shesh Pir River; in the Lake Maharlu basin in the Khoshk River, under Sa`di’s Tomb in Shiraz, the Soltanabad Marsh, and various springs such as Pirbanoo Spring (and see photographs and **Sources** below); in the Persis basin in the Ahram, Bahoosh, Berim, Dalaki, Dar ol Mizan, Fahlian, Faryab, Firuzabad, Helleh, Karzin, Kavar, Kheyrabad, Kohmareh Sorkhi, Mond,

Qarah Aqaj, Qasook, Rodbal (= Rudbar), Sarab-e Bahram, Sefid, Shapur, Sheldan, Shirin, Shiv, Shur, Tankab, Zanjiran and Zohreh rivers, and Lake Parishan; in the Tigris River basin in the Abshar, A`la, Ali Kalleh, Alvand, Aran, Armand, Arvand, Ateshkadeh, Avan Abbas, Bahmanshir, Bala, Bazoft, Beheshtabad, Berim, Beshar, Chaghalvandi, Chameshk, Chamgordan (= Cham-e Gordan), Changuleh (= Talkhab), Chardavol, Cheshmeh Gerdab, Chikhab, Cholvar, Davoud-Arab, Dez, Dinvar, Doirej, Eivashan (= Eushan), Gahar, Gamasiab, Gangir, Gaveh, Ghalate, Godarkhosh, Haramabad, Jagiran, Jarrahi, Kabgiyan, Kahman, Kahnak, Kaka Reza, Kalwi, Kangavar Kohneh, Kangir, Karkheh, Karun, Kashgan, Kashkan, Katola, Kerend, Khersan, Khorram (Khorramabad), Konjancham, Kouh Gari, Little Zab, Mar Bor, Marun, Mazoo, Morghab, Murani, Nahr-e Shavor, Palangan, Qareh Su, Qaveh, Qeshlaq, Qolalb, Qopal, Ravand, Razavar (= Raz Avar), Sabzab, Sarab Bahram, Sarghi, Sartang, Semirom, Sepidbarg (= Sefid Barg), Shavour, Shilaghab, Shush, Siahgav, Simareh, Sirvan, Solgan, Talkhab, Tangab, Tang-e Haft, Veisian, Yuzi Dar, Zard and Zimakan rivers, sarabs near Kermanshah, the Gamasiab and Haramabad wetlands in Hamadan Province, and the Qeshlaq Dam (Berg, 1949; Menon, 1964; Bianco and Banarescu, 1982; Gh. Izadpanahi, pers. comm., 1995; M. Rabbaniha, pers. comm., 1995; Abdoli, 2000; Yazdanpanah, 2005; Esmaeili and Piravar, 2007; Abbasi *et al*., 2009, 2020; Ghalenoei *et al*., 2010; Biokani *et al*., 2011; Teimori *et al*., 2011; Bahrami Kamangar *et al*., 2012a; Zareian *et al*., 2012; Bibak *et al*., 2013a; Biukani *et al*., 2013; Gerami *et al*., 2013; Pirani *et al*., 2013; Pazira *et al*., 2013, 2016; Shabani *et al*., 2013; Shabani and Askari, 2013; Golchin Manshadi *et al*., 2014, 2019; Jalili and Eagderi, 2014b; Ramin *et al*., 2014; Reyahi-Khoram *et al*., 2014; Sadeghi Limanjoob *et al*., 2014; Tabiee *et al*., 2014; Abdolhahi, 2015; Esmaeili *et al*., 2015; Hashemzadeh Segherloo *et al*., 2015; Keivany *et al*., 2015; Sayyadzadeh *et al*., 2015; Shahi *et al*., 2015; Vazirzadeh *et al*., 2015; Zamaniannejad *et al*., 2015; Alizadeh Marzenaki *et al*., 2016; Jouladeh-Roudbar *et al*., 2016; Keivany and Zamani-Faradonbe, 2016, 2017b; Kolangi Miandare, 2016; Taghiyan *et al*., 2016; Vesaghi *et al*., 2016; Yahyazadeh *et al*., 2016; Askari *et al*., 2017; Azizi *et al*., 2017; Mansouri Khajeh Langi *et al*., 2017; Pirali Khirabadi *et al*., 2017; Darvishi *et al*., 2018; Nasri and Eagderi, 2018; Fatemi *et al*., 2019; Hasankhani *et al*., 2019; Khamees *et al*., 2019; Zamani-Faradonbe *et al*., 2020; Nasri, 2021; Zamani-Faradonbe and Keivany, 2021a; Zamani-Faradonbe *et al*., 2021).

**Zoogeography.** The wide distribution in Southwest Asia and inadequate examination of variation may mask distinct taxa, although this is not apparent on morphometric and meristic grounds. If such variation is valid, then taxa may reflect vicariant events. See also under the genus. The recently-described *G. meymehensis* and *G. tiam* were found by DNA analyses of fish thought previously to be *G. rufa*.

**Habitat.** This species is found in rivers, streams, lakes, dams, lagoons, ponds, marshes, springs and qanats. This is the commonest species in catches in southwestern Iran, followed by *Cyprinion macrostomus* (e.g., see Tabiee *et al*. (2014)) and the commonest species in, for example, the Gongir or Gangir River in Ilam (Dadashi *et al*., 2014) and the Shur River at Lali in the Karun River basin (Abdolhahi, 2015). It had the highest percentage of frequency (23.49%) of fish in the Beshar River (Golchin Manshadi *et al*., 2019). Such a wide distribution encompasses a variety of environmental conditions. In areas under human influence in Lorestan, such as the lower reaches of rivers and near cities, it is more common than in higher, pristine waters. As well as grazing on exposed rock surfaces in streams, it can be found under pebbles on the stream bed.

Shabani and Askari (2013) examined fish from two rivers in Khuzestan using

microsatellite loci and were able to distinguish the populations. The Kheyrabad River population live under poorer environmental conditions based on diminution of genetic variation decreasing adaptation to environmental alterations.

Makki *et al*. (2021) forecasted climate-change effects by modelling seven environmental variables (basin, stream slope, bank-full width, elevation, mean air temperature, air temperature range, and annual precipitation). This species showed both expansion and reduction under different climate-change scenarios in 2050 and 2080.

It has been caught at 30°C on 24 November 1976 in a spring near Farrashband, Fars (CMNFI 1979-0129). In Khuzestan, it was observed swimming free, under pebbles or adhering to the rock sides of a pool (CMNFI 1979-0375).

Habitat of *Garra rufa*, CMNFI 1979-0019,
Fars, Barm-e Baba Haji near Shiraz, 26 January 1976, Brian W. Coad.

Habitat of *Garra rufa*, CMNFI 1979-0019,
Fars, Barm-e Baba Haji spring source near Shiraz, 26 January 1976, Brian W. Coad.

Habitat of *Garra rufa*, CMNFI 1979-0046,
Fars, Barm-e Dalak Spring, Lake Maharlu, 17 March 1976, Brian W. Coad.

Habitat of *Garra rufa* (and *Cyprinion macrostomus*), CMNFI 1979-0374,
Khuzestan, stream tributary to Bala River, 29 January 1978,
Brian W. Coad.

**Age and growth.** Esmaeili and Ebrahimi (2006) gave a *b* value of 2.919 based on 291 Iranian fish measuring 2.28-11.82 cm standard length. Hashemzadeh Segherloo *et al*. (2015) examined 364 fish, 4.8-17.0 cm total length, from 13 rivers of Iran and found *b* values ranged from 2.74 to 3.19 with an average of 2.99 in the Tigris River basin and 2.82 to 3.14, average 2.96, in the Persian Gulf (Persis) basin. Keivany *et al*. (2015) examined 28 populations and found a *b* value range of 2.75-3.4, mean 3.1 for 147 Tigris basin fish in nine rivers with a total length of 32.19-122.83 mm; 2.91-3.19, mean 3.02 for 121 Karkheh basin fish in six rivers with length 19.82-172.85 mm; 2.85-3.18, mean 3.06 for 62 Karun basin fish in four rivers with length 36.94-130.93 mm; 2.63-3.27, mean 3.06 for 103 Persis basin fish in eight rivers with length 19.82-172.85 mm (*sic* for all Persis basin, correctly 22.45-106.09); and 3.34 for one river in the Hormuz basin with length 33.48-75.74 mm. The overall *b* value was 3.11. The

majority of populations showed isometric growth.

Yazdanpanah (2005) examined fish from the Zanjiran Spring-Stream system, Firuzabad (Persis basin) and found the sex ratio to be equal. Bibak *et al*. (2013a) gave a length-weight relationship for 52 fish, 3.2-13.7 cm total length from the Shapur River as $W = 0.012L^{3.242}$ indicating positive allometry. A Dalaki River sample of 324 fish, 3.0 to 17.1 cm total length, had 4 age classes, growth was isometric (*b* = 2.89 for males and 2.93 for females) and growth parameters were $L_\infty = 164.14$, $W_\infty = 117.11$, $t_0 = -1.16$ and K = 0.189 for females and $L_\infty = 168.16$, $W_\infty = 116.28$, $t_0 = -1.14$ and K = 0.213 for males (Pazira *et al*., 2013).

Abedi *et al*. (2010) examined the age in 364 fish, 29.11 to 151.27 mm total length, in the Armand River in the Karun River basin. Length and weight were significantly correlated (W = -5.076 + 3.112 logTL for sexes combined, -5.092 + 3.134 logTL for males and -5.036 + 3.089 logTL for females), growth was isometric, numbers of males and females were not significantly different, life span was up to 4 years and most fish were 2-3 years old. Patimar *et al*. (2010) examined fish, 4.8-10.2 cm total length, from the Kangir River in Ilam and found a maximum age of $5^+$ years, the most frequent size class was 65-70 mm for both sexes, negative allometric growth in both sexes, a balanced overall sex ratio but with males predominant at smaller sizes and females at larger sizes, and von Bertalanffy growth parameters were $L_\infty$ = 108.453 mm, $K$ = 0.449 year$^{-1}$, $t_0$ = 0.192 years for males and $L_\infty$ = 115.516 mm, $K$ = 0.420 year$^{-1}$, $t_0$ = 0.088 years for females. Males grew faster than females. The growth index $\phi'$ was 8.572 for males and 8.631 for females. Fish were smaller and of lower weight than fish from the Zanjiran spring stream system in Fars, southern Iran studied by Yazdanpanah (2005), and this was attributed to severe ecological conditions. The Zanjiran fish had a similar most frequent size class of 60-70 mm, but growth was positively allometric and the sex ratio was more balanced. Gerami *et al*. (2013) found 535 Cholvar River fish (Karun River basin) to have a length-weight relationship of $W = 5E\text{-}06TL^{3.225}$ for males, $W = 6E\text{-}06TL^{3.156}$ for females and $W = 5E\text{-}06TL^{3.196}$ for both sexes, and growth was positive allometric. The condition factors were 1.212 for males, 1.217 for females and 1.218 for both sexes, showing that the species was in fair to good condition in this river. Mansouri Khaje Langi *et al*. (2014) found a length-weight relationship of $W = 0.015L^{3.001}$ for fish from the Sirvan River and $W = 0.052L^{2.95}$ for the Palangan River, both in the Tigris River basin, and condition factors were 1.6 in the Sirvan and 4.61 in the Palangan. Bahrami Babaheydari (2013) found a length-weight relationship for 110 fish from the Marun River was $W = 0.926TL^{1.1665}$ for females and $W = 0.746TL^{1.1015}$ for males, both indicating negative allometric growth. Keivany and Zamani-Faradonbe (2016) gave a *b* value of 2.72 for 30 fish, 3.0-7.2 cm total length, from the Zohreh River. Vesaghi *et al*. (2016) recorded values from 194 fish at eight stations from the Dinawar River as infinite length $L_\infty$ = 124.57 mm, growth factor K = 0.29, male:female sex ratio 1:1.44 and length-weight relationship $W = 1.000095L^{2.97}$. Growth was isometric in summer and autumn and allometric in winter and spring. Growth was faster in males. The habitat was assessed as proper for spawning and as a nursery. Keivany and Zamani-Faradonbe (2017b) examined 108 fish, 27.2-135.4 mm total length, from the Jarrahi River and found a *b* value of 3.06. Azizi *et al*. (2017) sampled 34 fish from the Sirvan River and found the maximum total length and weight were 8.2 cm and 7.22 g for females, 8.2 cm and 7.1 g for males, the length-weight relationship for females was $W = 0.0252TL^{2.68}$, for males was $W = 0.0119TL^{3.03}$, and the total relationship was $W = 0.0114TL^{3.06}$, showing positive allometric growth for the population and males and negative allometric growth for females. The condition factor was estimated as 1.19 in males, 2.53 in females and the total condition factor was 1.0. Abbasi *et al*. (2019) gave a *b* value of

3.2 for 142 fish, 2.4-12.3 cm total length, from the Gamasiab River.

Rahemo (1995) reported fish up to age 7 from the Tigris River, Iraq in a parasitological study.

Çiçek *et al*. (2021) examined 365 specimens from the Merzimen Stream, Euphrates River basin of Turkey between May and November 2013. The age ranged from 0 to 5 years, total length and weight varied from 2.9 to 16.8 cm, mean 9.67 cm, and 0.21 to 69.27 g, mean 15.69 g, respectively. The length-weight relationship was $W = 0.0124L^{2.9888}$ indicating isometric growth. Estimated population parameters were calculated as $L_\infty = 19.98$ cm, $k = 0.275$, $t_0 = -1.157$. Fulton's condition factor and growth performance index were estimated as $K = 1.24$ and $\Phi' = 2.04$. Total (Z), natural (M), and fishing (F) mortalities and the exploitation rate (E) were estimated at 0.452, 0.295, 0.156, and 0.347, respectively.

**Food.** Gut contents include diatoms, algae and large quantities of sand in fish examined from Iran. Barmar *et al*. (2019) examined the diet of fish in the Gheshlagh (= Qeshlaq) River, Kurdistan and found stomach emptying indices showing relative overeating, the fish were herbivores and the most important dietary items were the diatom species *Nitzschia*, *Gomphonema*, *Diatoma*, *Cocconeis*, *Amphora* and *Cymbella*, respectively.

Younis *et al*. (2001b) found Shatt al Arab fish feeding mainly on organic detritus, followed by diatoms and algae, with arthropods ranking third. A study by Yalçin-Özdilek and Ekmekçi (2006) in the Asi (= Orontes) River in Turkey demonstrated that this species is a grazer on aquatic plants, mostly consisting of benthic cyanobacteria, chrysophytes and phytoplankton with included rotifers and protozoans. Both season and location in a stream affected the composition of the diet with season the most important factor.

**Reproduction.** High temperatures and poor food conditions in some Iranian habitats may be limiting factors in reproduction for this species. The Zanjiran Spring-Stream system had fish with eggs up to 1.75 mm in diameter, fecundity up to 2,396 eggs, and a relative fecundity of 86.8. The gonadosomatic, modified gonadosomatic and Dobriyal indices increased from November to April when they were 16.98, 20.454 and 1.27 respectively. Values decreased in May presumably indicative of spawning but increased during June with a slight fall from July to November, perhaps indicating late spawning of some fish. The highest gonadosomatic index for males was in March and for females in April with maximum averages at 6.49 for males and 16.98 for females. Atretic oocytes, low fecundity, a hermaphrodite specimen and abnormalities in the caudal fin and lateral line in some fish suggests the population is under stress in a poor habitat (Yazdanpanah, 2005). The Armand River population (Abedi *et al*., 2010) had a prolonged and active reproductive season from March to September, an adaptation to unstable environmental conditions. All mature oocytes were spawned at once but some may be retained for later spawning. In addition, different individuals released eggs and sperm at different times. Average egg diameter was 0.67 mm, maximum 1.98 mm, with highest diameter in May and the lowest in November. Absolute and relative fecundity were 1,179.65 and 109.4 respectively on average. Maximum absolute fecundities reached 3,794 eggs. The Kangir River fish (Patimar *et al*., 2010) had a maximum fecundity of 13,927 eggs and a maximum relative fecundity of 2,345.72 eggs/g. Egg diameters reached 1.7 mm. Reproduction occurred in April-May with the highest average gonadosomatic index for males of 4.21 in April and for females of 7.85 in May. The Zanjiran population (Yazdanpanah, 2005) had a range and mean of absolute fecundity much lower than that in the Kangir River (184-2,396, mean 760 versus 1,680-13,927, mean 5,806), as was relative fecundity. Vazirzadeh *et al*. (2015) found fish from the Beshar River, Yasuj spawning spontaneously in aquaria when

the water temperature was raised to 28°C.

Al-Rudainy (2008) gave sexual maturity at 2-3 years, 10.0 cm in length and a weight of 50.0 g for Iraqi fish. Spawning took place in May and June with eggs deposited on vegetation and rocks with a relative fecundity up to 542 eggs/g. Bardakci, Ozansoy and Koptagel (at www.epress.com/w3jbio/vol5/bardakci/paper.htm, downloaded 29 March 2001) noted depression of vitellogenesis in a hot spring population in Turkey, perhaps due to temperature and starvation. A nearby stream population had a higher gonadosomatic index. Ovaries increased in size and weight from May to July in both localities although the hot spring had fewer mature oocytes and more atretic oocytes at various development stages.

**Parasites and predators.** Jalali and Molnár (1990a) recorded two monogenean species, *Dactylogyrus* spp., from this species in the Dez River, Khuzestan. Gussev *et al*. (1993b) described two new species, *Dactylogyrus rectotrabus* and *D. acinacus*, from the Dez River fish. Jalali *et al*. (2005) summarised the occurrence of *Gyrodactylus* species in Iran and recorded *G*. sp. from fish in the Helleh River. Golchin Manshadi *et al*. (2017) recorded *Cucculanus* sp. and *Dactylogyrus alatus* from fish in the Shapur River, Fars. Maleki *et al*. (2018) recorded metacercariae of the trematode *Clinostomum complanatum* from fish in the Qeshlaq River basin.

This species is eaten by *Silurus triostegus* (Mesopotamian catfish) at Baghdad (notes on a specimen in the Field Museum of Natural History, Chicago (FMNH 51251)).

**Economic importance.** Ündar *et al*. (1990) identify this species and *Cyprinion macrostomus* as the "doctor fish" of the Kangal hot spring in Turkey (Warwick and Warwick, 1989; Kürkçüoğlu and Öz, 1989; Bardakci, Ozansoy and Koptagel at www.epress.com/w3jbio/vol5/bardakci/paper.htm, downloaded 29 March 2001, Bilke, 2004; Anonymous, 2007; and various newspaper and television reports). The fish have been used in this way in Turkey for over 200 years (Bhattacharya, 2016). High water temperatures around 35°C reduce the amount of plankton available as fish food and the fish nibble away infected skin of humans who bathe in these waters. This fish is known as "licker" (and *Cyprinion macrostomus* as "striker") from its behaviour in the spa pools. The healing properties are linked to the high level of selenium (1.3 p.p.m.) in the water, selenium being beneficial in some skin diseases, and possibly UV light. The fish facilitate the action of the selenium and UV light by softening and clearing away psoriatic plaque and scale, exposing the lesions to the water and sunlight. However, some lesions are made worse and the fish could cause some new ones. Bhattacharya (2016) mentioned an enzyme (dithranol/anthralin) in the fish mouth which helps remove dead skin and improves skin regeneration. *Garra rufa* is now widely used in commercial facilities around the world for treating skin diseases and removing dead skin. There is some danger of bacterial infection and transmission of human diseases as the fish cannot be sanitised between customers.

Jarvis (2011) gave a biological synopsis of this species, published in Canada, since it is increasingly being used in private spa facilities and may escape into the wild. This usage apparently stresses the fishes (*Practical Fishkeeping*, downloaded 27 July 2012). Catarino *et al*. (2019) studied feeding quantity and frequency levels in order to maintain this fish for ichthyotherapy. Yahyazadeh *et al*. (2016) noted its presence in Iran and as a commercial species.

This species is also used as an ornamental fish for its appearance and aquarium-cleaning ability (Vazirzadeh *et al*., 2015). It has been caught on worm bait in the Dalaki River by A. Shiralipour (November 1976, CMNFI 1979-0125).

*Garra rufa* as “doctor fish”,
(Doctor fish, CC BY 2.0, Dina Middin).

**Experimental studies.** Vazirzadeh *et al*. (2014) used ovaprim, a commercial spawning inducing agent, on fish from the Kohmareh Stream (Helleh River basin) under hatchery conditions. Ovaprim was effective in inducing spawning but a low dosage must be used to avoid brooder mortality. Feeding *Artemia* nauplii during the weaning stage resulted in a higher survival rate of fish larvae than those fed phytoplankton and infusoria.

**Conservation.** This is a common species with a wide distribution and it is not under any specific threat in Iran. Vulnerable in Turkey (Fricke *et al*., 2007). Listed as of Least Concern by the IUCN (2015).

**Sources.** Type material:- *Discognathus rufus* (NMW 53240 and SMF 553), *Discognathus obtusus* (NMW 53238 and SMF 5408) and *Discognathus crenulatus* (NMW 53236 and 53237), and see comments above on other possible types.

Iranian material:- CMNFI 1970-0540, 7, 22.2-41.4 mm standard length, Fars, qanat south of Kazerun (no other locality data); CMNFI 1979-0018, 48, 21.5-64.9 mm standard length, Fars, Barm-e Shur (29º28'N, 52º41'30"E); CMNFI 1979-0019, 4, 28.9-35.4 mm standard length, Fars, Barm-e Baba Haji (29º23'N, 52º40'E); CMNFI 1979-0021, 4, 16,7-28.7 mm standard length, Iran, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0022, 2, 64.3-80.0 mm standard length, Iran, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0023, 2, 35.0-51.5 mm standard length; CMNFI 1979-0026, 2, 21.5-22.3 mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0027, 1, 50.5 mm standard length, Fars, Chehel Cheshmeh (ca. 29º43'N, ca. 52º04'E); CMNFI 1979-0033, 34, 23.7-72.0 mm standard length, Fars, Barm-e Shur (29º28'N, 52º41'30"E); CMNFI 1979-0036, 1, 36.4 mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0045, 16, 20.0-59.2 mm standard length, Fars, Sa`di’s Tomb, Shiraz (29º37'N, 52º35'E); CMNFI 1979-0046, 1, 43.7 mm standard length, Fars, qanat at Barm-e Dalak (ca. 29º35'N, ca.

52º38'E); CMNFI 1979-0047, 2, 36.2-67.6 mm standard length, Fars, spring source of Ab-e Paravan marshes (ca. 29º34'N, ca. 52º42'E); CMNFI 1979-0048, 1, 40.1 mm standard length, Fars, spring and marsh northeast side of Lake Maharlu (ca. 29º32'N, ca. 52º48'E); CMNFI 1979-0075, 33, 12.5-57.1 mm standard length, Fars, Mond River at Pol-e Kavar (29º11'N, 52º41'E); CMNFI 1979-0085, 3, 58.2-63.1 mm standard length, Fars, Hosseinabad (no other locality data); CMNFI 1979-0109, 1, 74.3 mm standard length, Fars, Mond River at Shahr-e Khafr (28º56'N, 53º14'E); CMNFI 1979-0111, 8, 30.7-62.0 mm standard length, Fars, stream on Shiraz-Bushehr road (29º37'30"N, 52º21'E); CMNFI 1979-0112, 5, 55.0-77.1 mm standard length, Fars, stream draining Soltanabad Marshes (29º29'N, 52º38'30"E); CMNFI 1979-0113, 4, 40.8-63.7 mm standard length, Fars, Sa`di’s Tomb, Shiraz (29º37'N, 52º35'E); CMNFI 1979-0115, 5, 57.7-66.5 mm standard length, Fars, Sa`di’s Tomb, Shiraz (29º37'N, 52º35'E); CMNFI 1979-0120, 5, 27.6-66.3 mm standard length, Bushehr, Dalaki River near Konar Takhteh (29º28'N, 51º21'E); CMNFI 1979-0125, 2, 99.0-121.4 mm standard length, Bushehr, Dalaki River near Dalaki (ca. 29º28'N, ca. 51º21'E); CMNFI 1979-0128, 6, 26.6-32.1 mm standard length, Fars, Shur River between Atashkadeh and Firuzabad (28º51'N, 52º31'E); CMNFI 1979-0129, 43, 24.8-46.9 mm standard length, Fars, spring 2 km north of Farrashband (28º54'N, 52º04'E); CMNFI 1979-0131, 10, 16.9-46.6 mm standard length, Fars, Abarak River (28º38'N, 52º49'E); CMNFI 1979-0132, 11, 23.1-49.5 mm standard length, Fars, Shur River 54 km from Firuzabad (28º35'N, 52º58'E); CMNFI 1979-0157, 12, 40.6-88.6 mm standard length, Fars, qanat stream at Hadiabad (28º52'N, 54º13'E); CMNFI 1979-0158, 13, 35.3-54.2 mm standard length, qanat jube over Qasook River (28º54'N, 53º53'30"E); CMNFI 1979-0161, 11, 43.1-92.2 mm standard length, Fars, qanat on Neyriz to Shiraz road (29º10'30"N, 53º41'E); CMNFI 1979-0195, 3, 44.3-59.4 mm standard length, Fars, jube on road to Fasa (ca. 28º54'N, ca. 53º53'30"E); CMNFI 1979-0199, 4, 37.3-45.0 mm standard length, Fars, qanat 18 km from Jahrom (ca. 28º23-25'N, ca. 53º31-40'E); CMNFI 1979-0200, 5, 27.6-43.6 mm standard length, Fars, Mond River tributary 13 km from Jahrom (28º36'N, 53º36'30"E); CMNFI 1979-0202, 9, 19.1-25.1 mm standard length, Fars, Mond River (29º01'N, 53º00'E); CMNFI 1979-0206, 2, 50.9-51.9 mm standard length, Fars, qanat near Runiz-e Pa’in (29º12'N, 53º40'E); CMNFI 1979-0241, 6, 35.7-49.2 mm standard length, Fars, Shapur River at Shapur (29º47'N, 51º35'E); CMNFI 1979-0271, 8, 34.7-56.7 mm standard length, Lorestan, river in Kashkan River drainage (33º39'N, 48º32'30"E); CMNFI 1979-0273, 15, 40.9-58.2 mm standard length, Lorestan, Kashkan River drainage 5 km from Khorramabad (33º26'N, 48º19'E); CMNFI 1979-0274, 3, 24.4-32.8 mm standard length, Lorestan, river in Kashkan River drainage (33º27'N, 48º11'E); CMNFI 1979-0275, 7, 38.6-60.5 mm standard length, Lorestan, Kashkan River 2 km from Ma’mulan (33º25'N, 47º58'E); CMNFI 1979-0276, 10, 42.1-70.0 mm standard length, Lorestan, Chameshk River (ca. 33º19'N, ca. 47º53'30"E); CMNFI 1979-0277, 1, 128.4 mm standard length, Lorestan, Kashkan River drainage (33º30'N, 47º59'30"E); CMNFI 1979-0278, 12, 53.9-89.3 mm standard length, Lorestan, Kashkan River drainage, Sarab Dowrah (33º34'N, 48º01'E); CMNFI 1979-0279, 9, 33.5-117.3 mm standard length, Lorestan, Khorramabad River (33º37'N, 48º18'E); CMNFI 1979-0288, 43, 22.9-102.3 mm standard length, Ilam and Poshtkuh, Gangir River at Juy Zar (33º50'N, 46º18'E); CMNFI 1979-0289, 5, 55.5-101.7 mm standard length, Kermanshah, river in Diyala River drainage (34º28'N, 45º52'E); CMNFI 1979-0290, 6, 24.1-54.9 mm standard length, Kermanshah, river in Qasr-e Shirin (34º31'N, 45º35'E); CMNFI 1979-0291, 7, 24.9-66.8 mm standard length, Kermanshah, river in Diyala River drainage (34º24'N, 45º37'E); CMNFI 1979-0293, 8, 92.1-101.3 mm standard length, Fars, Mond River at Kavar (29º11'N, 52º41'E); CMNFI 1979-0304, 2, 41.6-43.0 mm standard

length, Fars, Lake Parishan (ca. 29º31'N, ca. 51º50'E); CMNFI 1979-0350, 4, 28.1-33.5 mm standard length, Khuzestan, Marun River near Marun (30º39'30"N, 50º02'E); CMNFI 1979-0364, 4, 36.0-50.6 mm standard length, Khuzestan, river at Abdolkhan (31º52'30"N, 48º20'30"E); CMNFI 1979-0365, 2, 32.1-32.8 mm standard length, Khuzestan, stream in Doveyrich River drainage (32º25'N, 47º36'30"E); CMNFI 1979-0368, 4, 25.3-47.7 mm standard length, Khuzestan, Karkheh River (32º24'30"N, 48º09'E); CMNFI 1979-0369, 4, 24.9-37.7 mm standard length, Khuzestan, Shush River at Shush (32º12'N, 48º14'30"E); CMNFI 1979-0371, 1, 37.3 mm standard length, Khuzestan, stream in Karkheh River drainage (32º05'N, 48º19'E); CMNFI 1979-0374, 1, 62.2 mm standard length, Khuzestan, stream tributary to Bala River (32º40'N, 48º15'E); CMNFI 1979-0375, 10, 37.9-71.1 mm standard length, Khuzestan, stream tributary to Bala River (ca. 32º45'N, ca. 48º14'30"E); CMNFI 1979-0378, 1, 49.3 mm standard length, Khuzestan, stream tributary to Karkheh River (ca. 32º48'N, ca. 48º04'E); CMNFI 1979-0379, 1, 63.1 mm standard length, Khuzestan, Dez River (32º12'N, 48º27'E); CMNFI 1979-0382, 3, 34.7-38.0 mm standard length, Khuzestan, Karun River at Shushtar (32º03'N, 48º51'E); CMNFI 1979-0387, 2, 48.2-64.5 mm standard length, Khuzestan, stream 12 km from Haft Gel, Jarrahi River drainage (31º25'N, 49º38'E); CMNFI 1979-0388, 1, 55.2 mm standard length, Khuzestan, Zard River 21 km north of Ramhormoz (31º19'N, 49º44'E); CMNFI 1979-0389, 2, 43.8-57.7 mm standard length, Khuzestan, Zard River at Bagh-e Malek (31º31'N, 49º53'30"E); CMNFI 1979-0390B, 10, 33.8-69.7 mm standard length, Khuzestan, stream tributary to Zard River (31º29'N, 49º54'30"E); CMNFI 1979-0391, 1, 39.7 mm standard length, Khuzestan, stream in Marun River drainage (31º28'N, 49º51'E); CMNFI 1979-0392, 1, 42.6 mm standard length, Khuzestan, Zard River (ca. 31º32'N, ca. 49º48'E); CMNFI 1979-0396, 3, 22.7-35.1 mm standard length, Kheyrabad River 20 km from Behbehan (30º32'N, 50º23'30"E); CMNFI 1979-0397, 2, 52.4-59.5 mm standard length, Khuzestan, stream tributary to Kheyrabad River (30º30'N, 50º28'E); CMNFI 1979-0398, 1, 37.6 mm standard length, Kohgiluyeh and Bowyer Ahmad, stream in Zohreh River drainage (30º24'30"N, 50º37'30"E); CMNFI 1979-0399, 1, 41.0 mm standard length, Fars, stream in Zohreh River drainage (30º19'30"N, 51º15'E); CMNFI 1979-0497, 2, 52.4-60.3 mm standard length, Fars, Mond River at Band-e Bahman (29º11'N, 52º40'E); CMNFI 1979-0501, 8, 24.7-48.9 mm standard length, Fars, Mond River at Kavar (29º11'N, 52º41'E); CMNFI 1987-0217, 5, 35.8-55.6 mm standard length, Khuzestan, Karun River at Kut Abdollah (31º13'N, 48º39'E); CMNFI 1991-0155, 1, 48.5 mm standard length, Hamadan, Gamasiab River (34º12'N, 48º20'E); CMNFI 1993-0125, 1, 85.8 mm standard length, Kermanshah, Sarab-e Nilufar (34º24'N, 46º52'E); CMNFI 1993-0141, 1, 86.5 mm standard length, Bushehr, Dalaki River (29º28'N, 51º15'E); CMNFI 1993-0149, 1, 121.7 mm standard length, Khuzestan, Karun River (no other locality data); CMNFI 1995-0009A, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 1995-0010, not kept, Khuzestan, A`la River, 2 km above Pol-e Tighen (31°23.5'N 49°54'E); CMNFI 2007-0063, 5, 40.1-65.9 mm standard length, Fars, Mond River tributary near Jahrom (28º36'N, 53º37'E); CMNFI 2007-0065, 1, 81.2 mm standard length, Fars, Barm-e Dalak (ca. 29º35'N, ca. 52º38'E); CMNFI 2007-0066, 2, 47.1-55.3 mm standard length, Fars, Sa`di's Tomb, Shiraz (29º37'N, 52º35'E); CMNFI 2007-0100, 2, 48.4-54.8 mm standard length, West Azarbayjan, Kalwi Chay near Piranshahr (ca. 36º44'N, ca. 45º10'E); CMNFI 2007-0109, 10, 54.7-78.3 mm standard length, Kordestan, Qeshlaq River basin (ca. 35º16'N, ca. 47º01'E); CMNFI 2007-0110, 1, 84.9 mm standard length, Kordestan, Yuzi Dar River basin (ca. 35º05'N, ca. 46º56'E); CMNFI 2007-0111, 11, 26.5-64.5 mm standard length, Kermanshah, Alvand River near Sar-e Pol-e Zahab (ca. 34º36'N, ca. 45º56'E);

CMNFI 2007-0112, 19, 43.1-54.3 mm standard length, Kermanshah, Kerend River basin near Shahabad-e Gharb (ca. 34º06'N, ca. 46º30'E); CMNFI 2007-0116, 4, 25.8-31.7 mm standard length, Kermanshah, Gamasiab River basin west of Sahneh (ca. 34º28'N, ca. 47º36'E); CMNFI 2008-0102, 1, 84.9 mm standard length, Kermanshah, sarabs near Kermanshah (no other locality data); CMNFI 2008-0120, 23, 17.7-125.5 mm standard length, Khuzestan, Rud Zard at Rud Zard (31º22'N, 49º43'E); CMNFI 2008-0121, not kept, Khuzestan, Zard Rud at Bagh-e Malek (31º32'N, 49º55'E); CMNFI 2008-0130, not kept, Khuzestan, stream at Kupal (31º15'N, 49º10'E); CMNFI 2008-0132, 1, 117.9 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); CMNFI 2008-0151, 1, 116.1 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); CMNFI 2008-0160, not kept, Khuzestan, Avan Abbas River at Bagh-e Malek (31º31'16"N, 49º52'32"E); CMNFI 2008-0161, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 2008-0163, not kept, Khuzestan, Marun River at Chahar Asiab (30º40'28"N, 50º09'34"E); CMNFI 2008-0165, not kept, Khuzestan, Dez River near Shush (32º14'40"N, 48º20'07"E); CMNFI 2008-0167, 1, 35.9 mm standard length, Khuzestan, stream above Diuni Darreh (32º37'42"N, 48º41'40"E); CMNFI 2008-0171, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'20"N, 49º52'44"E); CMNFI 2008-0175, 2, 46.9-74.5 mm standard length, Lorestan, Kahman River at Dow Ab-e Aleshtar (33º47'N, 48º12'E); CMNFI 2008-0182, 1, 79.8 mm standard length, Chahar Mahall and Bakhtiari, Ab-e Bazoft Sofla (31º38'06"N, 50º28'30"E); CMNFI 2008-0184, 2, 59.0-59.2 mm standard length, Chahar Mahall and Bakhtiari, Armand River (31º37'N, 50º47'E); CMNFI 2008-0191, 1, 57.7 mm standard length, Chahar Mahall and Bakhtiari, Ab-e Bazoft (31º38'06"N, 50º28'30"E); CMNFI 2008-0254, 5, 73.3-89.8 mm standard length, Fars, Qarah Aqaj River (29º31'03"N, 52º15'E); CMNFI 2008-0256, 5, 73.1-101.3 mm standard length, Fars, stream at Dimeh Mil-e Bala (30º06'52"N, 51º27'18"E); CMNFI 2008-0259, 3, 67.6-96.0 mm standard length, Fars, Atashkadeh Stream near Fasa (28º56'18"N, 53º38'54"E); CMNFI 2008-0261, 2, 107.3-122.0 mm standard length, Fars, Shesh Pir River near Sepidan (29º58'19"N, 52º24'04"E); CMNFI 2008-0263, 4, 73.9-99.4 mm standard length, Fars, Qarah Aqaj River (29º31'03"N, 52º15'E); CMNFI 2008-0269, 2, 40.4-85.3 mm standard length, Fars, Ab-e Garm Simakan, Jahrom (28º30'N, 53º30'E); CMNFI 2008-0270, 1, 67.6 mm standard length, Fars, Zanjiran Stream, Firuzabad (29º02'29"N, 52º33'55"E); CMNFI 2008-0271, 2, 72.3-78.5 mm standard length, Fars, Kohmarreh Sorkhi River (28º22'54"N, 53º08'54"E); CMNFI 2008-0274, 2, 40.3-47.6 mm standard length, Fars, Akbarabad, Fasa (28º56'18"N, 53º38'54"E); CMNFI 2008-0293, 1, 36.0 mm standard length, Fars (no other locality data).

Comparative material:- BM(NH) 1931.12.21:9-10, 2, 94.9-95.5 mm standard length, Iraq, Mosul (36º20'N, 43º08'E); BM(NH) 1973.5.21:187-188, 2, 67.6-73.1 mm standard length, Iraq, Tigris River at Jadriyah (no other locality data); BM(NH) 1974.2.22:1418, 1, 67.4 mm standard length, Iraq, Khalis (33º49'N, 44º32'E); BM(NH) 1974.2.22:1441-1444, 4, 48.9-86.3 mm standard length, Iraq, Baghdad (33º21'N, 44º25'E); BM(NH) 1986.2.14:2-3, 2, 64.8-91.8 mm standard length, Iraq, Baghdad (33º21'N, 44º25'E).

## ***Garra*** sp. Kul River

*Garra* sp., 56.6 mm standard length, CMNFI 1979-0156,
Bronwyn Jackson @ Canadian Museum of Nature.

*Garra* sp., ventral view, 56.6 mm standard length, CMNFI 1979-0156,
Bronwyn Jackson @ Canadian Museum of Nature.

**Common names.** None.

[Kul River garra].

**Systematics.** This material was initially distinguished by me because the caudal fin branched ray count was modally 17 like *G. rufa* to the west while the dorsal fin branched ray count was modally 7 like *G. persica* to the east. This material could then represent introgression between the two aforementioned species or a distinct species. Sayyadzadeh *et al*. (2015) considered that fish from the Golabi and Qalatoyeh springs (see below) could be populations of *G. persica* or *G. rufa* introgressed with *G. mondica*. Molecular data from Esmaeili *et al*. (2016) and Mousavi-Sabet *et al*. (2019) suggested the Kul River *Garra* is in fact a distinct species. Nuclear rhodopsin data in Behrens-Chapuis *et al*. (2015) also confirmed this

distinction.

**Key characters.** The possession of 17 caudal fin branched rays and 7 dorsal fin branched rays are distinctive, along with distribution.

**Morphology.** This taxon has a typical *Garra* morphology. The body is rounded and fairly deep, being deepest in front of the dorsal fin because of the rounded belly. The dorsal profile in front of the dorsal fin is straight to slightly convex and leads to a rounded snout. The caudal peduncle is compressed and deep. The snout has a slight groove in front of the nostril in larger fish. The eye is positioned midway between the snout tip and the end of the operculum. The mouth is subterminal. The mental disc is round to ovoid in shape, heavily papillose anteriorly in a band across the anterior part of the disc, lightly papillose on the rest of the disc. The snout folds over the upper lip and has a fringed edge and bears papillae. The four barbels are thin but evident with the anterior one extending back to the level of the nostrils or slightly beyond and the posterior one to the anterior half of the eye. The dorsal fin margin is emarginate and its origin is well anterior to the level of the pelvic fin origin. The depressed dorsal fin does not extend back as far as the level of the origin of the anal fin. The caudal fin is moderately forked with rounded tips. The anal fin margin is slightly emarginate to rounded and extends back to, or just short of, the procurrent caudal fin rays. The pelvic fin margin is rounded to straight and extends back to the anus which is 2-4 scales in advance of the anal fin origin. One specimen lacked pelvic fins. The pectoral fin margin is rounded to straight and the fin does not extend back to the pelvic fin.

Meristic values are:- dorsal fin unbranched rays 3, dorsal fin branched rays 7(27) or 8(6) (mean 7.2, S.D. 0.39), anal fin unbranched rays 3, anal fin branched rays 5(33), pectoral fin branched rays 12(1), 13(3), 14(18), 15(10) or 16(1) (mean 14.2, S.D. 0.78), pelvic fin branched rays 7(20) or 8(12) (mean 7.4, S.D. 0.49), and caudal fin branched rays 16(1), 17(31), 18(1) or 19(1) (mean 17.1, S.D. 0.42). Lateral line scales 31(2), 32(7), 33(14), 34(9) or 35(1) (mean 33.0, S.D. 0.94). Scales are regularly arranged over the body. The anterior breast is scaled. Upper flank scales have a rounded posterior margin, short parallel sides which soon curve to form the posterior margin, the anterior corners are distinct, and the anterior margin is slightly rounded to almost straight, being wavy or with a central prominence flanked on each side by a concave section. There are numerous fine circuli, a subcentral anterior focus, and numerous radii on the posterior field, fewer radii on the anterior field and none to a few radii on the lateral fields. Total gill rakers number 18-21. Total vertebrae 33(9), 34(16), 35(6) or 36(2) (mean 34.0, S.D. 0.85). Material from the Golabi and Qalatoyeh springs near Darab have 7(18) or 8(12) dorsal fin branched rays and 16(5) or 17(22) caudal fin branched rays and are less distinctive than my material on meristic grounds (Sayyadzadeh *et al*., 2015).

Zareian *et al*. (2021) described scale abnormalities from fish in the Eij River of the Kul River basin, presumably this species.

**Sexual dimorphism.** Unknown.

**Colour.** Preserved material is an overall uniform brown, somewhat lighter on the belly but not strongly contrasting. There is a spot at the upper end of the opercular opening on the body and a caudal spot or blotches. There is dark pigment at the bases of the dorsal fin behind rays 2-5, in some only behind rays 2-3. Dorsal fin membranes bear irregular lines of pigment but these form no pattern of bars across the fin. Caudal fin rays and some adjacent membranes have elongate pigment lines but these are not arranged in a pattern. The anal and pelvic fins are immaculate or have some lines of pigment and the pectoral fin has melanophore spots on the rays and membranes, but all these last three fins are fairly faintly pigmented.

**Size.** Reaches 56.7 mm standard length.

**Distribution.** This species is found in three localities in the upper Kul River basin near Darab, Fars, draining to the Straits of Hormuz, local river drainages being the Shur River ca. 20 km west of Darab, and the Gelal and Rudbal (= Rudbar) rivers just west of Darab (see below). Sayyadzadeh *et al*. (2015) recorded material from the Golabi and Qalatoyeh springs, the Haji Abad River and the Fadami Stream, also near Darab which may also be this taxon. Zareian *et al*. (2021) recorded fish from the Eij River, Estahban in the Kul River basin that may too be this species.

**Zoogeography.** See generally under the genus.

**Habitat.** This species is found in rivers, streams, springs and qanats. The qanat and spring habitats were 23ºC on 30 November 1976 (CMNFI 1979-0156) while the river was 10ºC on 31 January 1977 (CMNFI 1979-0193). Conductivity in the three localities listed below in **Sources** was 0.3-0.45 millimhos and pH 6.2-6.5. The qanat was cloudy and polluted while the river and spring were clear and colourless.

Fars, Golabi Spring, Kul River basin, Azad Teimori and Hamid Reza Esmaeili.

**Age and growth.** Unknown.

**Food.** Unknown but presumably similar to other *Garra*.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

**Economic importance.** None**.**

**Experimental studies.** None

**Conservation.** Distribution is limited to the upper reaches of a river basin and the species may be subject to drought and pollution as two of the known localities are a spring and a qanat with limited water supplies and the river probably dries in part in summer.

**Sources.** Type material:- Not yet described.

Iranian material:- CMNFI 1979-0155, 11, 27.1-42.9 mm standard length, Fars, spring at Gavanoo (28º47'N, 54º22'E); CMNFI 1979-0156, 20, 33.8-56.7 mm standard length, Fars, qanat in Rashidabad (28º47'N, 54º18'E); CMNFI 1979-0193, 3, 22.8-27.1 mm standard length, Fars, Gelal River 8 km from Darab (28º45'N, 54º27'30"E).

***Garra tashanensis***

Mousavi-Sabet, Vatandoust, Fatemi and Eagderi, 2016

*Garra tashanensis*, Khuzestan, Tashan Cave, Jalal Valiallahi.

**Common names.** Mahi kor-e Tashan (=Tashan blind fish).

[Tashan blind cave garra, Tashan cave fish, Tashan cave blind fish].

**Systematics.** The holotype is under VMFC GT-H (Vatandoust and Mousavi-Sabet Fish Collection, Tehran), 22.0 mm standard length, Khuzestan, Tashan Cave, Tigris River drainage

(30°51'91"N, 50°10'49"E). Paratypes are under VMFC GT-P1 to VMFC GT-P3, 3, 24.0-27.0 mm standard length, same data as the holotype. This taxon is in a distinct lineage, separate from other *Garra* species including other cave fishes in Iran and elsewhere.

*Garra tashanensis*, holotype, VMFC GT-H, Hamed Mousavi-Sabet.

*Garra tashanensis*, paratypes, VMFC GT-P1 to VMFC GT-P3, Hamed Mousavi-Sabet.

**Key characters.** This species is distinguished from its congeners by lacking eyes and pigment, a round mental disc (versus absence of mental disc in *G. typhlops*, elliptical mental disc in *G. lorestanensis*), a well-developed rostral cap (rostral cap poorly developed in *G. lorestanensis*), a wide and midterminal mouth (versus small and subterminal in *G.*

*lorestanensis*), rare scales on anterior body (versus naked body in *G. lorestanensis*), and no obvious pores on the lateral line (lateral line with 28-35 pores in *G. lorestanensis*). *Garra tashanensis* is also distinguished from all other congeners in a comparison group including Iranian, Iraqi and Omani cave fishes, by having four fixed, diagnostic nucleotide substitutions in the mtDNA COI barcode region, and from the subterranean Iranian congeners by a K2P nearest-neighbor distance of 10.4% to *G. lorestanensis* and 11.8% to *G. typhlops*.

**Morphology.** The body is broadest at, or slightly behind the pectoral fin base, where it is moderately compressed. The caudal peduncle is compressed and deep. The body is deepest at, or slightly in front of, the dorsal fin base origin. The dorsal head profile rises gently from the tip of the snout and is slightly convex. The ventral profile is slightly concave on the pectoral-pelvic contour, and more or less straight from the pelvic to the anal fin origin. The head is moderate in size, and deeply depressed. The snout is roundish and the lower profile resembles that of *Garra typhlops*. The well-developed rostral cap is fimbriate and papillate on the lower surface, almost covering the lip. The mental disc is almost round, with a long and wide head through the roots of the maxillary barbel. Papillae are present on the antero-median fold. There is a well-developed groove between the antero-median fold (*sic*) and the central callous-pad is narrow and deep. There are scattered, small papillae on the latero-posterior flap and the surface of the central callous pad has sparsely arranged small papillae. The body is naked but rarely scales (1-3) are present on the anterior body around the pectoral fin origin. This species differs from *Garra lorestanensis* in the transverse lobe lacking small, sparse tubercles, and there is no obvious shallow transverse groove between the transverse lobe and the proboscis, even in small individuals. The proboscis is elevated from the depressed rostral surface. Two pairs of barbels are present, the maxillary ones being shorter. The margin of the dorsal fin is straight or slightly concave, and the margin of the anal fin is straight or slightly convex. The dorsal fin origin is anterior to the pelvic fin origin level. The caudal fin is distinctly forked and lobe tips are pointed. The anal fin does not reach back to the caudal fin base. The pelvic fin extends back to the anus. The pectoral fin reaches back 40-45% of the distance between the pectoral and pelvic fins.

Dorsal fin with 3 unbranched and 7 branched rays, anal fin branched rays 4-5, pectoral fin branched rays 12-14, and pelvic fin branched rays 6-7.

**Sexual dimorphism.** Unknown, specimens available being small and perhaps immature.

**Colour.** In live specimens, the body is pinkish to red from the blood visible through the skin. The gill filament area and lower part of head are bright red. The skin over the brain is semi-transparent, so that the brain is seen as a dark spot in some specimens. The intestine may have darkish contents visible through the body wall. In preserved specimens, the body is yellowish-white. All fins are hyaline in both live and preserved specimens.

**Size.** Reaches 29.0 mm standard length (J. Valiallahi, pers. comm., 2016).

**Distribution.** Restricted to Tashan Cave, a subterranean limestone system of the Zagros Mountains in Tashan District, Behbehan County, Khuzestan Province in the Marun River basin which drains west to join the Jarrahi River and the head of the Persian Gulf. The cave is 550 m northeast of the village of Bajak Sarjoushehr at 30º51′54″N, 50º10′32″E, altitude 490 m, and about 35 km from Behbehan City. Khalaji-Pirbalouty *et al*. (2018) give the locality as 30°51'54"N, 50°10'29"E at Sarjooshar Village. The cave is about 288 km from the cave locality of *G. lorestanensis* and *G. typhlops*.

**Zoogeography.** See above under **Systematics**.

**Habitat.** This species is found in a cave habitat described by Mousavi-Sabet *et al*. (2017) as follows:- "the only known entrance for the cave (may be not the main entrance), is very small about 2 sq m, which is not enough big for an effortless entry. After the entrance, there is a narrow corridor with downward sloping. After about 120 m the corridor reaches to the main cave, the soffit of the area is about 7-8 m, the first pool is located in this area, at a depth of about 90 m. The first pool area is about 30 $m^2$, with a maximum depth of about 2 m. Our initial estimate at the locality showed that there are at least 30-40 fish specimens in the pool. After about 500 m away the first pool in the main cave, there is the second pool at a depth of about 95 m underground. The second pool area is about 20 $m^2$, with a maximum depth of about 2.5 m, the soffit of this area is about 10-12 m. Our initial estimate showed that there are at least 30-60 fish specimens in the second pool. Both pools were stagnant, no water flow was observed at the sampling time (Summer 2016). The only water inlet was the water droplets from the ceiling of the cave. The air temperature inside the main cave was 20°C, and the water temperature was 17°C". J. Valiallahi (pers. comm., 2016) noted that Experts of the Iran Cultural Heritage, Handcrafts and Tourism Organization have estimated the length of this cave at about 3 km, with about 500 m explored. Local environmental experts, Engineer Farokh ShirAli and his colleagues Mr. Sabetifar, Mr. Feghhi and Mr. Fathi, first examined the Tashan Cave and caught three fish. The discovery of the new cave was published in local media by Sayed Attaollah Tahery, active in the field of environmental education, and appeared in Iran Environment and Wildlife Watch (http://ifpnews.com/sources/iew-news-website/, 6 August 2016).

Khuzestan, Tashan Cave habitat with fish, Hamed Mousavi-Sabet.

Khuzestan, Tashan Cave habitat with fish and the isopod *Stenasellus tashanicus*, after Khalaji-Pirbalouty *et al*. (2018).

Khuzestan, Tashan Cave surroundings and entrance, Hamed Mousavi-Sabet.

Khuzestan, Tashan Cave interior, Hamed Mousavi-Sabet.

**Age and growth.** Unknown.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** None reported.

**Economic importance.** None but could become an aquarium fish.

**Experimental studies.** None.

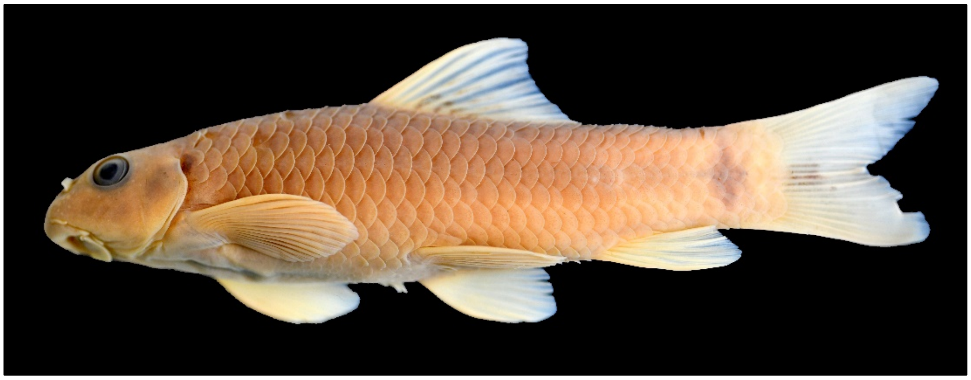
**Conservation.** The cave is readily accessible and the population could easily be exterminated by over collecting, by habitat destruction or by pollution. The extent of populations in any inaccessible portions of the underground system is unknown. Jouladeh-Roudbar *et al*. (2020) listed it as Critically Endangered because of its single locality and the threat of drought

**Sources.** Mousavi-Sabet *et al*. (2016) and manuscript data by J. Valiallahi and R. R. Motlagh, September 2016.

Iranian material:- None.

***Garra tiam***

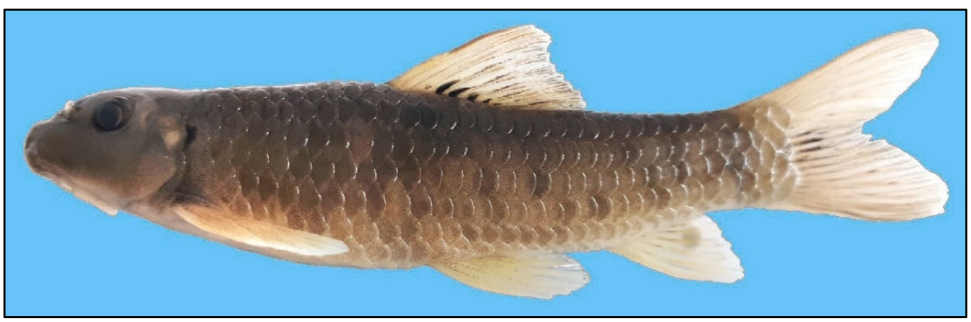
Zamani-Faradonbe, Keivany, Dorafshan and Zhang, 2021



*Garra tiam*, 63.3 mm standard length, CMNFI 1979-0384,
Khuzestan, river in Ab-e Shur drainage (32º00'N, 49º07'E).

**Common names**. None.

**Systematics.** The holotype is under IUT-IM (Isfahan University of Technology Ichthyology Museum) T43, 62.8 mm standard length, Khuzestan, Abshur (= Ab-e Shur) River at km 40 on the road from Masjed Soleyman to Haftgel, 31°41'33"N, 49°24'17"E and paratypes are under IUT-IM 13981018-01-01, 26, 29.0-70.8 mm standard length, collected with the holotype. The specific name *tiam* is derived from the word *tiam*, used to refer to someone with beautiful eyes in the language of the Lurish people in western Iran, including the area of the Abshur River. A name (*sic*, noun) in apposition.



*Garra tiam*, holotype, IUT-IM T43, Yazdan Keivany.

**Key characters.** *Garra tiam* is distinguished from other species of *Garra* in the Tigris River and Persis basins by a combination of characters, none unique to the species. The species has normal pigmentation, two pairs of barbels, 8 dorsal fin branched rays, and distribution in the Ab-e Shur basin. The mitochondrial COI barcode region also distinguishes the species (Zamani-Faradonbe *et al*., 2021).

**Morphology.** This is a small-sized and elongated species with a rounded body, deepest at or in front of the dorsal fin. The caudal peduncle length is 0.5-1.4 times longer than its depth, moderately deep. The dorsal head profile rises gently from the tip of the snout to the nape, and the dorsal profile of the back is slightly convex from the nape to the dorsal fin origin. The ventral profile is more or less straight between the pectoral fin insertion and the anal fin origin. The greatest body width is at, or slightly behind, the pectoral fin base, almost equal between the pectoral fin base and the dorsal fin origin. The head is moderately large (length 19.7-28.5% standard length) and slightly depressed (depth 60-88% head length), with a slightly convex or flat interorbital space, and height at nape less than head length. Head length is 0.8-1.4 times in body depth. The snout is rounded, its length 0.6-1.6 times in the postorbital length.

The transverse lobe has a tubercle, demarcated posteriorly by a shallow transverse groove in most specimens (groove sometimes absent). The transverse lobe is moderately separated from the lateral surface although the separation is not conspicuous in some specimens. The anterior arm of the depressed rostral surface does not reach to the base of the rostral barbel. There is no groove between the transverse lobe and the lateral surface in some individuals. There are no head tubercles in small individuals. The eye is relatively large, positioned at mid-head, and its diameter is 0.3-0.4 times in head depth and 0.3-0.5 times in interorbital width. There are two pairs of thin barbels, a maxillary barbel at the corner of the mouth, shorter (0.4-0.5 times) than the rostral barbel, the rostral barbel anterolaterally located, shorter (0.6-0.7 times) than eye diameter. The rostral cap is well-developed, fimbriate, and papillate on the ventral surface. The upper lip is present as a thin band of papillae arranged in some ridges. The upper jaw is almost or completely covered by the rostral cap. The mental disc is almost round, longer than wide and narrower than head width through the maxillary barbels. Papillae on the anterior fold of same size specimens are regularly arranged. The groove between the antero-medial fold and the central callous pad is narrow and deep, scattered small-sized papillae are on the latero-posterior flap, and the surface of the central callous pad is without, or with, sparsely arranged small papillae. The last unbranched dorsal fin ray is shorter than head length, the first branched ray is longest, the dorsal fin distal margin is slightly concave, the dorsal fin origin is closer to the caudal fin base than to the snout tip, the dorsal fin origin is well anterior to the level of the pelvic fin origin, and the tip of the last branched ray reaches the vertical to, or slightly in front of, the anus when folded down. The caudal fin is distinctly forked with the lobes pointed to rounded, the ventral lobe being larger than the upper lobe. The anal fin first branched ray is longest, the distal margin is straight or slightly concave, the fin origin is closer to the caudal fin base than to the pelvic fin insertion, and the depressed fin reaches back to the caudal fin base. The pelvic fin tip may, or may not, reach back to the anus or anterior margin of the anal fin and the insertion of the pelvic fin is closer to the anal fin origin than to pectoral fin insertion. The pectoral fin tip reaches approximately a point 3-4 scales anterior to the pelvic fin insertion, the fin length shorter than head length.

Meristic values from Zamani-Faradonbe *et al*. (2021) and material below are:- dorsal fin unbranched rays 2 and branched rays 7(1) or 8(33), anal fin unbranched rays 2 and branched rays 5, pectoral fin branched rays 11(14), 12(8), 13(10) or 14 (2), and pelvic fin branched rays 6(5), 7(25) or 8(4). Lateral line complete with 30(3), 31(4), 32(15), 33(8) or 34(4) scales, and 2-3 scales on the caudal fin base. Transverse scale rows above the lateral line 3(14), 4(12) or 5(8), scale rows between lateral line and pelvic fin insertion 3(23) or 4(11), between the lateral line and anal fin origin 3(22), 4(11) or 5(1), scales between the posteriormost pelvic fin base and the anus 5(14) or 6(3), and circumpeduncular scale rows 12(17), 13(17) or 14(1). There are 11 scales along the predorsal midline in one specimen, nine scales with free posterior margins in four specimens, and embedded scales in others. The anus is 2(14) or 3(3) scales distant from the anal fin origin. The chest is scaleless and the belly is covered with scales with free posterior margins. Scales are squarish with a rounded posterior margin, straight to slightly rounded dorsal and ventral margins, rounded and abrupt antero-dorsal and antero-ventral corners, and a vertical to slightly rounded anterior margin with a wavy edge. Radii are present on all fields, numerous in the posterior field, The focus is sub-central anterior and there are many fine circuli. Pharyngeal teeth are 5,3,2 in the left arch, the teeth being slightly hooked or pointed with a large flat surface below the tip. Total gill rakers

18(3), 19(5), 20(9), 21(6) or 22(1), reaching the raker adjacent or just past when appressed Total vertebrae 33(6) or 34(2).

**Sexual dimorphism.** Medium to large tubercles are sparsely set on the proboscis, largest on its anterior margin. Medium to large tubercles are scattered through the lateral and dorsal surfaces of the snout reaching the anterior nostril in most specimens, or the posterior orbital margin in a few specimens. The depressed rostral surface lacks tubercles.

**Colour.** Live fish have a grey to brown background colour. The head is grey to green. The iris is orange with a dark brown spot on the upper and lower portions. The upper surface of the rostral barbel is pale grey. There is a black, dark-brown or light blue blotch at the anteriormost lateral line. Scales on the flank are greenish-brown and dark grey, whitish or pale grey on the ventral flank and belly. Fins are hyaline to yellowish, the pectoral and pelvic fins golden yellow with black dots, and the dorsal, caudal and anal fins with black blotches or dark pigment lining the rays. The bases of dorsal fin rays 3-7 and part of the adjacent membranes have elongated black bars. Preserved fish have the dorsal surface of the head, back and flank dark brown to black. The iris is black. The upper surface of the rostral barbel is grey. There is a predorsal stripe. There are single or groups of dark-brown scales on the flank. The ventral surface of the head, mouth, chest and abdomen are whitish yellow. A large, 2-3 scales wide, black or dark-brown blotch is on the distal portion of the caudal peduncle, very conspicuous in most specimens, faded in a few. The central 2-5 rays of the caudal fin have proximal pigment. Pectoral, pelvic and anal fins are yellow to dark brown or mostly immaculate. Some black to dark-brown blotches are present on the caudal fin membranes. Dorsal fin membranes have a black or dark grey blotch at the base, and some black or brown blotches or light speckling on the middle and distal dorsal fin membranes.

**Size.** Reaches 70.8 mm standard length.

**Distribution.** This species is found in the Tigris River basin in the perennial Abshur or Ab-e Shur, a tributary of the upper Karun River.

**Zoogeography.** See under *Garra meymehensis*.

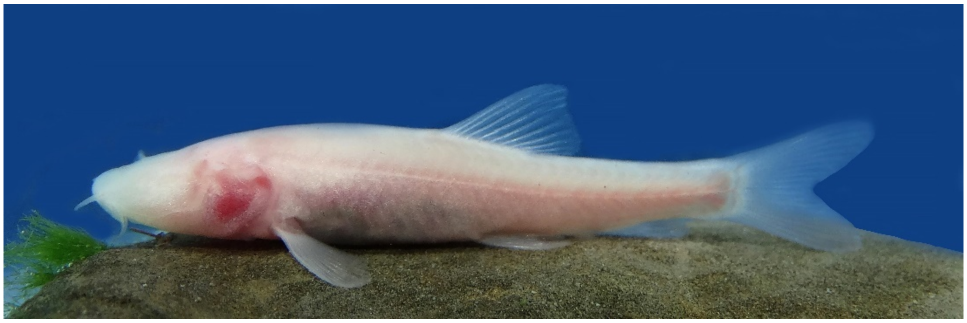
**Habitat.** This species is found in rivers and streams. Ab-e Shur means salt water and presunably indicates the saline nature of this river. Collection data included a temperature of 16-19ºC, pH 6.0, conductivity 4.1-10.5 mS, river width 12-30 m, slow to medium current, depth 40 cm, clear and colourless or cloudy water, mud, sand, gravel, pebbles, stone and bedrock bottoms, emergent vegetation and encrusting algae, and a grassy or barren shore. Fish were caught under pebbles.

Habitat of *Garra tiam* (and *Acanthobrama marmid*, *Arabibarbus grypus*, *Barilius mesopotamicus*, *Capoeta trutta* and *Cyprinion macrostomus*), CMNFI 1979-0384, Khuzestan, river in Ab-e Shur drainage, 30 January 1978, Brian W. Coad.

**Age and growth.** Unknown.
**Food.** Unknown.
**Reproduction.** Unknown.
**Parasites and predators.** None reported.
**Economic importance.** None.
**Experimental studies.** None.
**Conservation.** Numbers and potential threats are unknown.
**Sources.** Zamani-Faradonbe *et al*. (2021).

Iranian material:- CMNFI 1979-0383, 5, 31.9-53.0 mm standard length, Khuzestan, stream in Ab-e Shur drainage (31º59'30''N, 49º06'E); CMNFI 1979-0384, 1, 63.3 mm standard length, Khuzestan, river in Ab-e Shur drainage (32º00'N, 49º07'E); CMNFI 1979-0385, 2, 44.9-46.8 mm standard length, Khuzestan, stream in Ab-e Shur drainage (ca. 32º01'N, ca. 49º07'30''E); CMNFI 2008-0173, not kept, Khuzestan, Ab-e Shur drainage (31º53'N, 49º41'E).

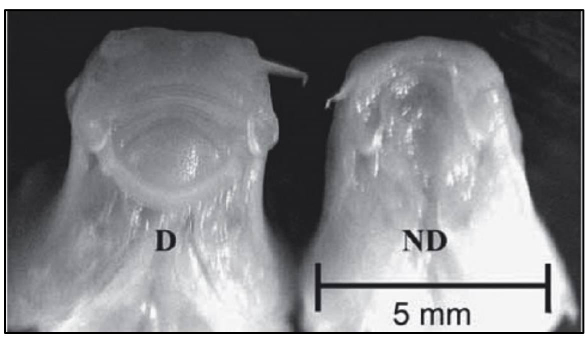
***Garra typhlops***
(Bruun and Kaiser, 1944)



*Garra typhlops*, Lorestan, Loven Cave, Hamed Mousavi-Sabet.

*Garra typhlops*, Lorestan, Loven Cave, Ruhollah Mehrani.

Lorestan, Loven cave, mix of cave fish, 11-19 May 2010
(all fish returned to cave alive), A. H. Zalaghi.




Chin region of *Garra lorestanensis*
(D = disc) and *G. typhlops* (ND = no disc),
after Farashi *et al*. (2014).

**Common names.** Kopur mahi kureghar, mahi kur, mahi kor-e ghar, mahi-ye kureghar or mahi-ye kur-e qar (= blind cave fish).

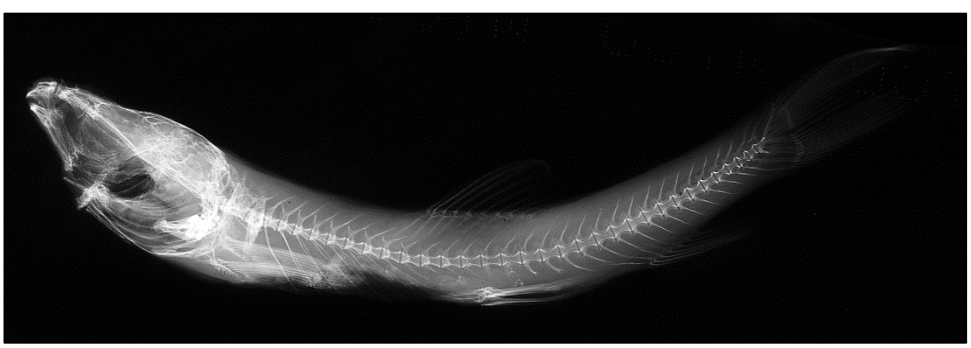
[Discless blind cave garra, Iran cave barb, Iranian cave barb, Zagros cave garra].

**Systematics.** The holotype of *Iranocypris typhlops* is in the Zoological Museum of Copenhagen (ZMUC P 26475) and measures 46.5 mm total length and 38.5 mm standard length (Nielsen, 1974; personal observations). The paratypes number five (in Nielsen (1974)), or six (in Bruun and Kaiser (1944)) but only four were found in ZMUC in December 1999. Paratypes (ZMUC P 26476, 26477, 26478, 26480) measure 19.5-42.0 mm total length and 16.5-34.5 mm standard length according to Bruun and Kaiser (1944). Two fish (P 26476 and P

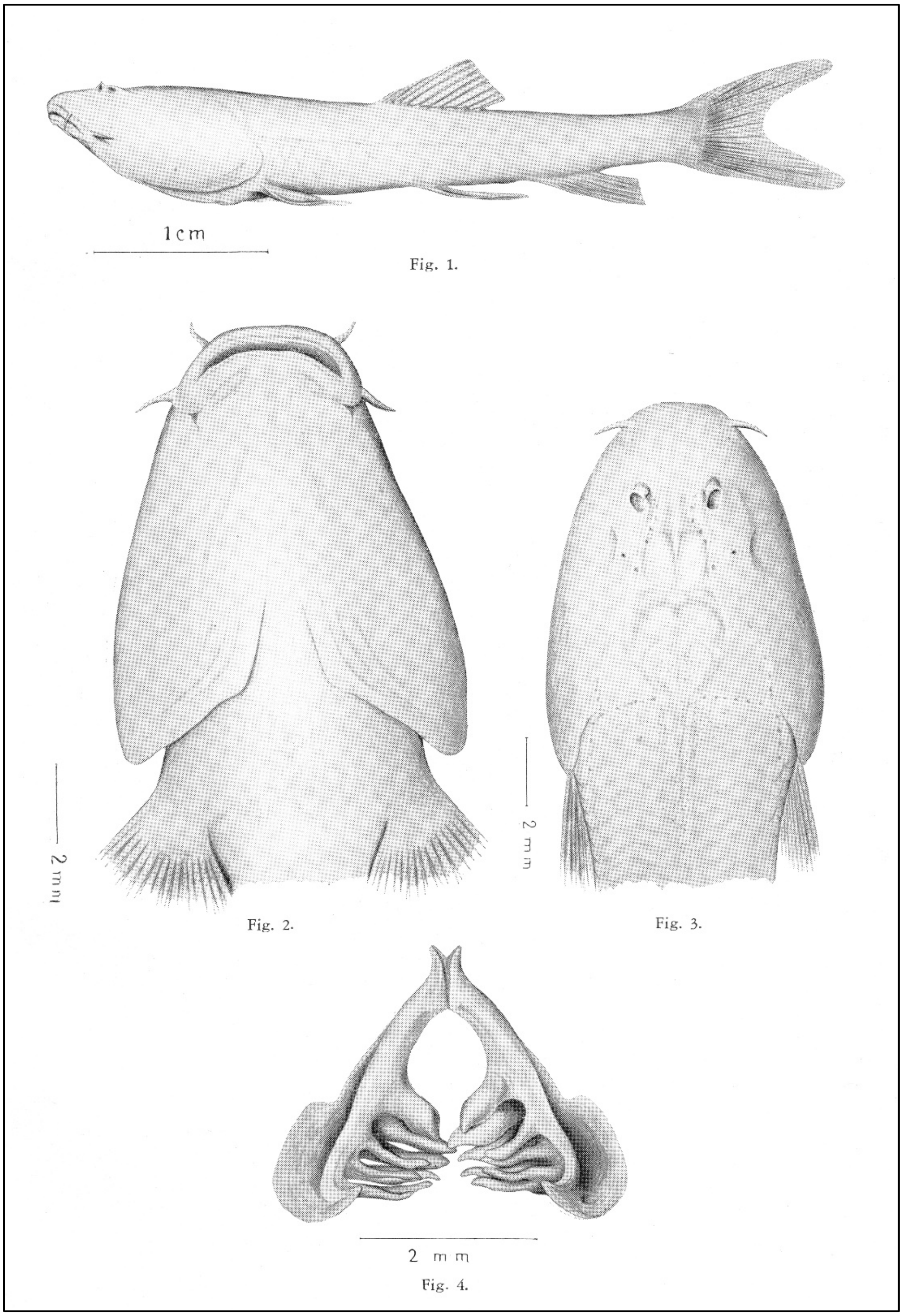
26480) were used in histological studies and one consists of the body only. The type locality is given below under **Distribution** and the fish were collected by E. Kaiser on 6-5-1937 from "lok 80" (= locality 80; but no field notes by E. Kaiser were available in ZMUC). The *Catalog of Fishes* has the date 1944 (downloaded 15 May 2018) as the journal dates to 1948, but a preprint may have appeared in 1944.

*Iranocypris typhlops,* holotype, ZMUC P 26475,
Azita Farashi, Natural History Museum of Denmark.

*Iranocypris typhlops,* holotype, ventral head, ZMUC P 26475,
Azita Farashi, Natural History Museum of Denmark.



*Iranocypris typhlops*, holotype, ZMUC P 26475,
Azita Farashi, Natural History Museum of Denmark.




*Iranocypris typhlops*, after Bruun and Kaiser (1944).

The authorship date for this species is listed variously as 1943 on an official reprint, as 1944-49 in one set of Contents, and “ready from the press 1944” in another set of contents. Proudlove (2006) stated that is did not appear until 1948 because of World War II. The *Catalog of Fishes* gave a date of 1944 (downloaded 1 August 2019).

Bruun and Kaiser (1944) believed this species to be related to the genus “*Barbus*”, members of which also have two pairs of barbels, although Saadati (1977) considered this unlikely since most “*Barbus*” from the Tigris River basin are large fishes.

*Iranocypris* Bruun and Kaiser, 1944 was synonymised with *Garra* by Farashi *et al*. (2014) on cytochrome *b* data. Both mental disc types formed a single clade and this clade was the sister group of a clade comprising *Garra rufa* (and *G. barreimiae* Fowler and Steinitz, 1956 from Oman). Hashemzadeh Segherloo *et al*. (2013), using the COI gene, compared this fish with *Barbus lacerta*, *Capoeta aculeata*, *C. trutta*, *Cyprinion macrostomus*, *Garra rufa*, *Kosswigobarbus* (= *Carasobarbus*) *kosswigi*, *K.* (= *Carasobarbus*) *sublimus*, *Luciobarbus barbulus* and *L. esocinus*, all species found in neighbouring rivers in the Zagros Mountains where the cave fish is located. A close relationship was found only with *Garra*. One fish without a mental disc carried a haplotype formerly reported for the form with a disc, indicating hybridisation of the two forms or the instability of the disc feature in these fishes. Hashemzadeh Segherloo *et al*. (2013) used mitochondrial DNA to compare this species with other *Garra* in Iran and found its closest affinity with fish from the Dez and Karun River basins. Jalili and Eagderi (2014b) found *Garra* and *Iranocypris* comprised a monophyletic group based on osteology of the caudal fin, and species could be separated on this osteology. Siahkalroodi *et al*. (2014) examined the 12S rRNA region for fish identified as *Iranocypris typhlops* and found one haplotype and no variation in the two fish sampled.

Hashemzadeh Segherloo *et al*. (2018) presented two possible scenarios for speciation in this cave habitat. The first involves two invasions with *typhlops* the first and *lorestanensis* (which still retains the mental disc like its surface relatives) the second. The second scenario is sympatric speciation after a single colonisation event. The authors analysed mitochondrial and nuclear DNA and found the two species are monophyletic and close to *G. gymnothorax*. An intermediate specimen shared more ancestry with *typhlops* (77%), indicating reproductive isolation is incomplete. A historical demographic analysis indicated that speciation occurred in sympatry following a colonisation event.

Hashemzadeh Segherloo *et al*. (2020) used the mtDNA cytochrome oxidase subunit I to compare fusiform and slender types of this species (and of *G. lorestanensis*) and found no differences. The analysis also showed that a limited level of gene flow (less than 3%) from *G. gymnothorax* of surface waters probably existed in *G. typhlops*. This low level of gene flow may be related to the lower fitness and adaptability of the surface dwelling fish to the subterranean life conditions.

**Key characters.** This species is eyeless, depigmented, and lacks a mental disc (present in *G. lorestanensis*, *q.v*., for further characters).

**Morphology.** The body is compressed and the head somewhat flattened. The body is deepest in front of the dorsal fin base, depth decreasing towards the caudal fin base. The greatest body width is at or slightly behind the pectoral fin base, the body almost equally wide until the dorsal fin origin. The dorsal head profile rises gently from the tip of the snout, slightly convex, sharply continuous with the dorsal body profile from about the middle between the tip of the snout and the nape to about the middle between the nape and dorsal fin origin. The ventral profile is slightly concave in the pectoral-pelvic contour, and more or less straight from the pelvic to the anal fin origin. The caudal peduncle is relatively shallow. There are two pairs of barbels, one pair at the mouth corners and one about half way along the upper lip. The upper lip has a feebly crenulated edge. The mouth is subterminal and horseshoe-shaped. The mental disc is absent. There is no visible trace of eyes in most fish. The skin has a few rows of scales behind the pectoral fin base, although some individuals may have more flank scales. A lateral line is present. There are about 32 myomeres along the flank and Jouladeh-Roudbar *et al*. (2020) gave 10-13 lateral line scales.

The dorsal fin has 3 unbranched and 7-8 branched rays (about equally divided), the anal fin has 3 unbranched and 4-5, usually 5, branched rays, the pectoral fin 12-17, usually 13-16, branched rays, and the pelvic fin 5-8, usually 6-7, branched rays. Gill rakers are very short, not reaching the adjacent raker when appressed and numbering 10-13 in total (Jouladeh-Roudbar *et al*. (2020) gave 20-24). Pharyngeal teeth are in 3 rows, 1 to 3 in the outer row, 3 to 4 in the middle row and 3-5 in the inner row. Anterior teeth are very enlarged and conical, appearing as rounded knobs while the posterior teeth in the main row are flattened and slightly hooked. Smaller fish have less conical anterior teeth with a tiny hook at the tip and posterior teeth have a short, flat to slightly concave surface below the tip. Tooth counts are difficult to make with accuracy, as it is not always clear to which row a tooth belongs. Smaller fish can be interpreted as 2,3,5-5,3,2 while larger fish may possibly lose a tooth and have a 2,3,4-4,3,2 count. Abbasi and Gharezi (2003) and Ebrahimi (2015) gave a 3,3,4 or 5-4 or 5,3,3 count. The gut is s-shaped. Total vertebrae number 34-36 (commonly 34, the holotype shown above 35).

The morphology and histology of the digestive tract was examined in detail by Abbasi and Gharezi (2003) and Ebrahimi (2015), and the urogenital system by Gharzi *et al*. (2011). The preorbital bones enclosing the infraorbital canal are absent, the posterior pharyngeal process of the basioccipital is broad and directed vertically with lateral ridges, the haemal spine of the fourth fused vertebra of the Weberian apparatus is narrow, and PU2 of the caudal skeleton is well-developed with a long neural spine (Mousavi-Sabet and Eagderi, 2016).

**Sexual dimorphism.** None reported.

**Colour.** This species is almost entirely unpigmented although live fish are pinkish to red from the blood showing through the skin. The gill filament area is bright red and some fish give an overall impression of red like a goldfish. Small, black pigment cells were visible in two small fish over the brain and just behind it and in these two fish and three others a very small, black pigment spot deep in the tissues on the side of the head may indicate a rudimentary but non-functional eye. Gut contents are visible through a semi-transparent body wall. Preserved fish are yellowish-white.

**Size.** Reaches 5.5 cm total length (Kiavash Golzarian, pers. comm., 6 April 2008), 7.4 cm standard length (Jalili and Eagderi, 2014c) and about 12.0 cm in captivity (Bagheri *et al*., 2016).

**Distribution.** Found originally at “Kaaje-ru” or Kayeh-ru, a small stream which drains the cave habitat above the garden “Bagh-e Loveh”, “Lowa” or “Levan” (Loven at 33°04'N, 48°37'E) which is about 4 km from kilometre 382 on the railway from Bandar-e Shapur (= Bandar-e Khomeyni) to Tehran and approximately 12 km north of the railway station Tang-e Haft. The stream below the cave locality is the Ab-e Serum, Sirom or Sirum which runs into the Ab-e Zezar or Sezar which is a tributary of the Dez River, in Lorestan Province. Note that Google Maps has this locality in Khuzestan Province. Further locality details were given in Bruun and Kaiser (1944). The locality is at 744 m and 33°04'38.6"N, 48°35'33.1"E according to the *Iranian Fisheries Research and Training Organization Newsletter*, 21:3, 1998 and Kiavash Golzarian, pers. comm., 6 April 2008).

Mahjoorazad and Coad (2009) reported a second locality on the Simareh River where a dam was being constructed at 33°16'56"N, 47°12'16"E. Groundwater penetrated an intake tunnel for a power house at 597 m altitude and formed a large pool where about 50 cave fish were seen. Only two specimens in poor condition were retained and resemble the disc form of *Garra lorestanensis*. This environment is now encased in concrete and no longer accessible. This locality is ca. 131 km in a direct line from the type locality and this cave fish may be

widespread in karst environments of the Zagros Mountains. A similar situation is seen in an unrelated amblyopsid species, *Typhlichthys subterraneus* in the U.S.A., which is found in karst areas across eight states in two major disjunct areas. This Iranian species may be widely distributed as Vatandoust *et al*. (2019) found cave fishes at a third locality, Tuveh Spring 31 km southeast of the Loven Cave, identified as both this species and *G. lorestanensis* based on molecular and morphological data. Vatandoust *et al*. (2019) also considered an alternative hypothesis to this wide distribution. While the haplotypes shared between Loven and Tuveh *G. typhlops* supports the hypothesis of a single population, this could be the result of recent colonisation of two separate aquifers by a single phylogenetically-young species. This hypothesis is partially supported by the substantial mitochondrial divergence between the populations of *G. lorestanensis*, although such differences are known in other single populations.

**Zoogeography.** The relationships of cave species, with their reduced characters, are problematical but the three rows of pharyngeal teeth and mouth structures indicate a relationship with *Garra*, now confirmed by DNA evidence. See also under the genus.

**Habitat.** This species is known primarily from a well-like but natural outlet of a subterranean system. The outlet overflows to form a small stream from January to May (Smith, 1979) during the snow-melt period in the Zagros Mountains but in April to June this flow ceases (the precise timing of flow and its cessation is estimated from villager’s comments and scientific visits and also varies with precipitation). Pictures of flowing water in May 2010 are shown in the account of a new genus name for the nemacheilid *Noemacheilus smithi* (Segherloo *et al*., 2016). The well area is about 5 by 3 m and gradually decreases as the year progresses. Divers descended to a depth of 60 feet (= 18.3 m) in 1977 in the “well” until the resurgence narrowed (Farr, 1977). A rope was let down by R. Mehrani (pers. comm., 2000) and reached 23 m before the rope ran out and yet it was not at the bottom. Smith (1979) reported divers descending to 60-70 feet (18.3-21.3 m). The pool shelves deeply under the cliff rearwards but the whole pool surface is exposed to light. There is no vegetation in the pool except for some encrusting algae on the rocky sides. The shale fragments forming the outermost floor of the pool have a thin layer of mud on them which may contain algae.

Hashemzadeh Segherloo *et al*. (2017, 2018) noted that this species could be observed year-round while its relative appears during pluvial periods (March-May) when there is water flow, indicating perhaps niche isolation driven by disc form and water flow. This may indicate character displacement allowing reduced competition.

It seems probable that a complex of flooded but narrow and inaccessible passages is the habitat of this species and the well is merely the surface manifestation of this complex (Bruun and Kaiser, 1944; Smith, 1978; Banister, 1992). There is a smaller pool (about 2 m across narrowing rapidly inside) and flowing exit stream lower down the gorge, about 50 m away from the main locality, where a blind fish was seen by me but not caught in December 2000 (Smith (1979) also tentatively reports sighting a fish here). This is assumed to be evidence of the interconnectivity of subterranean passages. The main pool was not flowing at this time. The stream from the smaller pool increases in flow downstream, possibly tapping more groundwater, and eventually has a moderate flow. No fish were seen in it. The stream falls over two high waterfalls (one estimated at 10-15 m high by Smith (1979) and both at 7-8 m by Hashemzadeh Segherloo *et al*. (2018)) so the well localities are isolated from the local fishes in the main river. The main river houses *Garra* and nemacheilid species. The stream shows evidence of recent higher flow which tends to confirm overflow from the main well.

The fish may be seen swimming freely in the well, up to 20 at a time may be counted. They can be caught with a dip-net.

Sampling on 4 December 2000 recorded a water temperature of 18.5°C, pH 7.5 and a conductivity of 334 µS. Aquarium specimens have been maintained at 5-28°C and were very resistant to changes in oxygen levels (R. Mehrani, pers. comm., 2000). Amir Hosin Zalaghi recorded the following parameters on 19 May 2010:- pH 7.3, 18.0ºC, conductivity 506.0 µS/cm, TDS 255.0 mg/l, $CO_3$ 0.0 mg/l, $HCO_3$ 152.0 mg/l, Cl 35.0 mg/l, $SO_4$ 65.0 mg/l, Ca 59.1 mg/l, Mg 27.8 mg/l, K 0.0 mg/l, Th 250.0 mg/l, turbidity 0.65 NTU, COD 3.0 mg/l. BOD 0.0 mg/l, total alkalinity 101.0, alkalinity-f 0.0, DO 7.9 mg/l, TSS 0.5 mg/l, $NO_3$ 0.5 mg/l, $NO_2$ 0.0 mg/l and Na 12.0 mg/l. Farashi *et al*. (2014) over a period of a year (May 2012-February 2013) found mean values to be pH 7.61, 18.41ºC (15-24ºC range), conductivity 458.59 µS/cm, TDS 244.46 mg/l, total suspended solids 0.53 mg/l, turbidity 0.56 NTU, dissolved oxygen 5.83 mg/l, $CO_3$ 0.0 mg/l, $HCO_3$ 149.54 mg/l, Cl 29.16 mg/l, $SO_4$ 58.57 mg/l, total nitrogen 1.3 mg/l, $NO_3$ 0.51 mg/l, $NO_2$ 0.0 mg/l, total phosphorus 0.59 mg/l, phosphate 0.34 mg/l, total sulphur 88.79 mg/l, COD 0.22 mg/l, BOD 0.01 mg/l, Ca 54.68 mg/l, Mg 19.48 mg/l, K 3.13 mg/l, Na 19.2 mg/l, and iron and total iron 0.0. Bagheri *et al*. (2016) gave values for three sampling times (winter 2009 and spring and summer 2010) pH 7.2-7.3, 16-20ºC, conductivity 504-527 µS/cm, TDS 255-266 mg/l, $CO_3$ 0.0 mg/l, $HCO_3$ 152-161 mg/l, Cl 26-35 mg/l, $SO_4$ 62-65 mg/l, Ca 58.7-59.9 mg/l, Mg 25.2-27.8 mg/l, K 0.0 mg/l, Th 243-250 mg/l, turbidity 0.59-0.69 NTU, COD 0-3 mg/l. BOD 0.0 mg/l, total alkalinity 101, alkalinity-f 0.0, DO 5.2-7.9 mg/l, TSS 0.5-0.6 mg/l, $NO_3$ 0.5 mg/l, $NO_2$ 0.0 mg/l and Na 12.0 mg/l.

The groundwater habitat on the Simareh River had the following readings after Mahjoorazad and Coad (2009):- pH 7.59, conductivity 1.5 m.mhos/cm, Cl 239.9 mg/l, $SO_4^{2+}$ 352.7 mg/l, $Ca^{2+}$ 142.7 mg/l, $Mg^{2+}$ 40 mg/l, $K^+$ 1.9 mg/l, total alkalinity 217.6 mg/l, $Na^+$ 160.4 mg/l, and suspended solids 26.9 mg/l.

Plankton composition of the type locality was given by Farashi *et al*. (2014) who found diversity and abundance to be low throughout the year in the cave, with an annual mean of 96.4 individuals/litre and no peaks during the year.

The Tuveh Spring has a seasonal flow, usually November to April, and fish were caught in a small rocky pool where they had been washed out from the spring. The spring outlet flows into a small stream.

Habitat of *Garra typhlops*, Lorestan, Loven Cave, 4 December 2000, Brian W. Coad.

Habitat of *Garra typhlops*, Lorestan, Loven Cave in flood,
11-19 May 2010, A. H. Zalaghi.

Habitat of *Garra typhlops*, Lorestan, Loven Cave
showing friable rock surrounds, 4 December 2000,
Brian W. Coad.

Lorestan, view towards Loven Cave, 4 December 2000,
Brian W. Coad.

Lorestan, waterfall below Loven Cave, 4 December 2000,
Brian W. Coad.

Lorestan, view up the cave valley from the Sezar River, 4 December 2000, Brian W. Coad.

**Age and growth.** Unknown although R. Mehrani (pers. comm., December 2000) kept fish in aquaria for 18-24 months (this may apply equally to *G. lorestanensis* and in **Food** below).

**Food.** Aquarium specimens referred to above were fed *Artemia*, dried and fine-ground *Gammarus*, zooplankton and phytoplankton. Faecal contents were phytoplankton and one fish was observed to scrape the aquarium wall. Occasionally aquarium fish would swim upside down with the snout at the water surface and may have been feeding on an algal film.

**Reproduction.** Unknown.

**Parasites and predators.** None reported directly although Bagheri *et al*. (2016) noted the presence of the predatory frog *Rana ridibunda* (= *Pelophylax ridibundus*) in the area which could feed on eggs.

**Economic importance.** Robins *et al*. (1991) listed this species as important to North Americans. Importance was based on its use in textbooks and its status as a cave fish.

**Experimental studies.** None.

**Conservation.** A fine of 10,000 rials (U.S. $139.94, 15 March 1978) was imposed specifically for illegal fishing of this species (Anonymous, 1977-1978), then 100,000 rials (U.S. $11.04, 7 April 2008, perhaps not a major deterrent). It was on the 1994 IUCN Red List of Threatened Animals as one of two rare fish species from Iran (with the nemacheilid, *Paracobitis* (= *Eidinemacheilus*) *smithi* also found at this locality) and is on the 2000 IUCN Red List and subsequent ones as VU D2 (Vulnerable, acute restriction in its area of occupancy (IUCN, 2015; Pishkahpour *et al*., 2018); see also Proudlove (2001)). Jouladeh-Roudbar *et a*l. (2020) listed it as of Least Concern for reasons given under *G. lorestanensis*. The cave fish was listed as a National Natural Heritage in 2005 (*Pars Today*, 27 February 2017).

The habitat is of unusual importance for studies on evolution in unique environments. Coad (2000), using 18 criteria, found this species to be one of the top four threatened species of freshwater fishes in Iran. Darvishvand *et al*. (2017) suggested that environmental officials of the province and country should reduce as much as possible the human and natural threats to

this species and mentioned its importance for tourism.

This species and *G. lorestanensis* may be widespread through the karst system of the Zagros. A second locality is ca. 131 km away, assuming this is the same taxon or taxa (Mahjoorazad and Coad, 2009) and a third locality, the Tuveh Spring, 31 km away has both species (Vatandoust *et al*., 2019). Both species are therefore only vulnerable at points of access. Arguably, perhaps these are the most secure fish in Iran!

B. Sandford (*in litt*., 1979) considered this fish to be endangered. The cave appeared to be a recently collapsed system and the network of fissures could be quite small. The main pool is at the end of a narrow cleft, overhung by a cliff of friable shale. Shale fragments fall spontaneously and the nearer end of the pool has a floor of shale fragments. Coupled with recent collecting the number of extant and accessible specimens may be quite low.

Local informants in December 2000 estimated that 5-6 parties visit the site each year. The number of specimens taken is unknown but an estimated 66+, possibly more than 100, have been collected from 2000 to 2008. Eight specimens are referred to in the literature, four specimens were caught in 1998 (R. Mehrani, pers. comm., 2000), in the two years 1999-2000 13 specimens were collected by one party, 18 by another in December 2000 (R. Mehrani and Iranian Fisheries Research Organization (IFRO) staff, N. Najafpour, IFRO, F. Razi, Darabad Museum, Tehran and Brian W. Coad), 10 specimens by Ali Ebrahimi (pers. comm., 25 January 2006), 11 by Kiavash Golzarian (pers. comm., 6 April 2008), and more than 10 by others. Bagheri *et al*. (2016) used mark-recapture methods on 245 fish from the accessible pool to estimate a population size of 405 or 434 fish using different methods, generally about 300-600 fish. Hashemzadeh Segherloo *et al*. (2018) captured 11 *G. typhlops* and 14 *G. lorestanensis*, the numbers limited by permit. The inaccessible population within the rock crevices is naturally unknown.

Four fish collected in 1998 survived two years in an aquarium (R. Mehrani, pers. comm., December 2000). They were fed on *Artemia*, zooplankton, phytoplankton and fine-ground *Gammarus*. Water temperature ranged from 5 to 28°C and resistance to changes in oxygen levels was high. Fish were sometimes observed to swim upside down at the water surface.

Farashi *et al*. (2013) and Farashie *et al*. (2013) carried out an analysis for the strategic management of this environment and found “unique habitat” from a Strengths group, “rock falls” from a Weakness group and “develop ecotourism” from an Opportunities group. Farashi *et al*. (2015) examined other caves in the region as potential sites for alternative habitats.

The establishment of a small park or reserve around the site and education of the local people to maintain a watch on the cave was advocated by me at www.briancoad.com and would be most useful to protect this species, and the other cave species at this site, from unauthorised collectors. A survey of the local people and the Department of the Environment files should be made to determine the numbers of visitors to this remote site. Hashemzadeh Segherloo *et al*. (2014) briefly outlined general educational sessions for local school children, data collection and publication on the cave site, and cooperation with local authorities for ecotourism development. Hashemzadeh Segherloo *et al*. (2016) explained the new generic name *Eidinemacheilus*, for the nemacheilid loach found there with the carps, is after the ranger, Eidi Heidari, protecting the site and *Nemacheilus* for loaches. Hashemzadeh Segherloo *et al*. (2018) noted that the Department of the Environment capture permits restrict the number of fish that can be taken.

This is a small species of fish of unusual appearance and provenance and could be bred

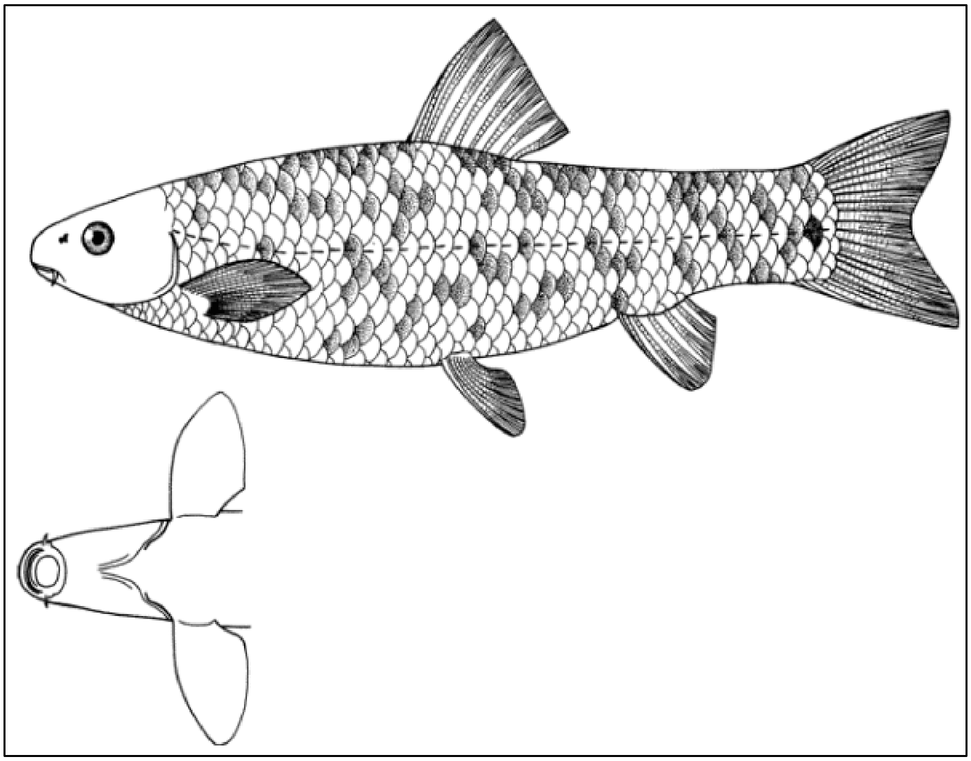
and sold as an aquarium and experimental species, providing that numbers at the site warrant removal of breeding stock. If successful, this would ensure survival of the species. Surveys of groundwater recharge in the area and a more thorough investigation of the cave system should be undertaken to assess the status of the habitat.

**Sources.** Movaghar (1973) is an additional reference, in Farsi, on this species. This blind cave species is placed in a world-wide context by Proudlove (1997a, 1997b).

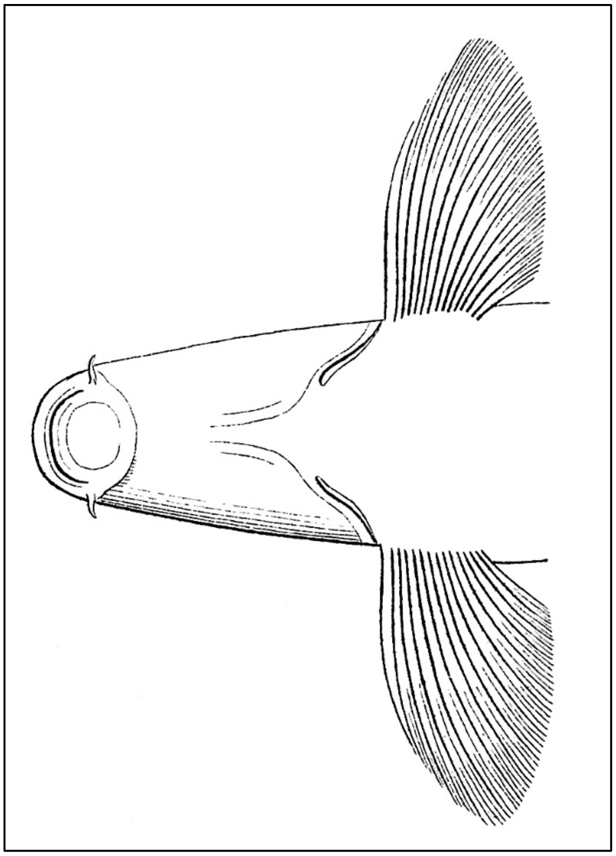
Type material:- *Iranocypris typhlops* (ZMUC P 26475, ZMUC P 26476, ZMUC P 26477, ZMUC P 26478 and ZMUC P 26480).

Iranian material:- CMNFI 2007-0124, 6, 27.3-42.2 mm standard length, type locality as above; CMNFI 2008-0177, 1, 30.4 mm standard length, type locality as above.

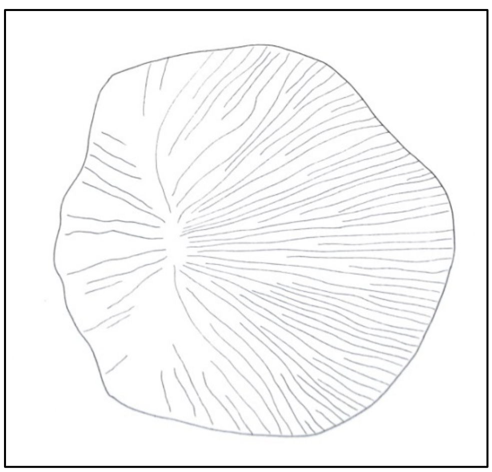
## ***Garra variabilis***
(Heckel, 1843)



*Garra variabilis*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Garra variabilis*, ventral head, after Heckel, 1843b).



*Garra variabilis*, scale, Freidhelm Krupp.

*Garra variabilis*, Turkey, Diyarbakır, Tigris River, Bismil, Cüneyt Kaya.

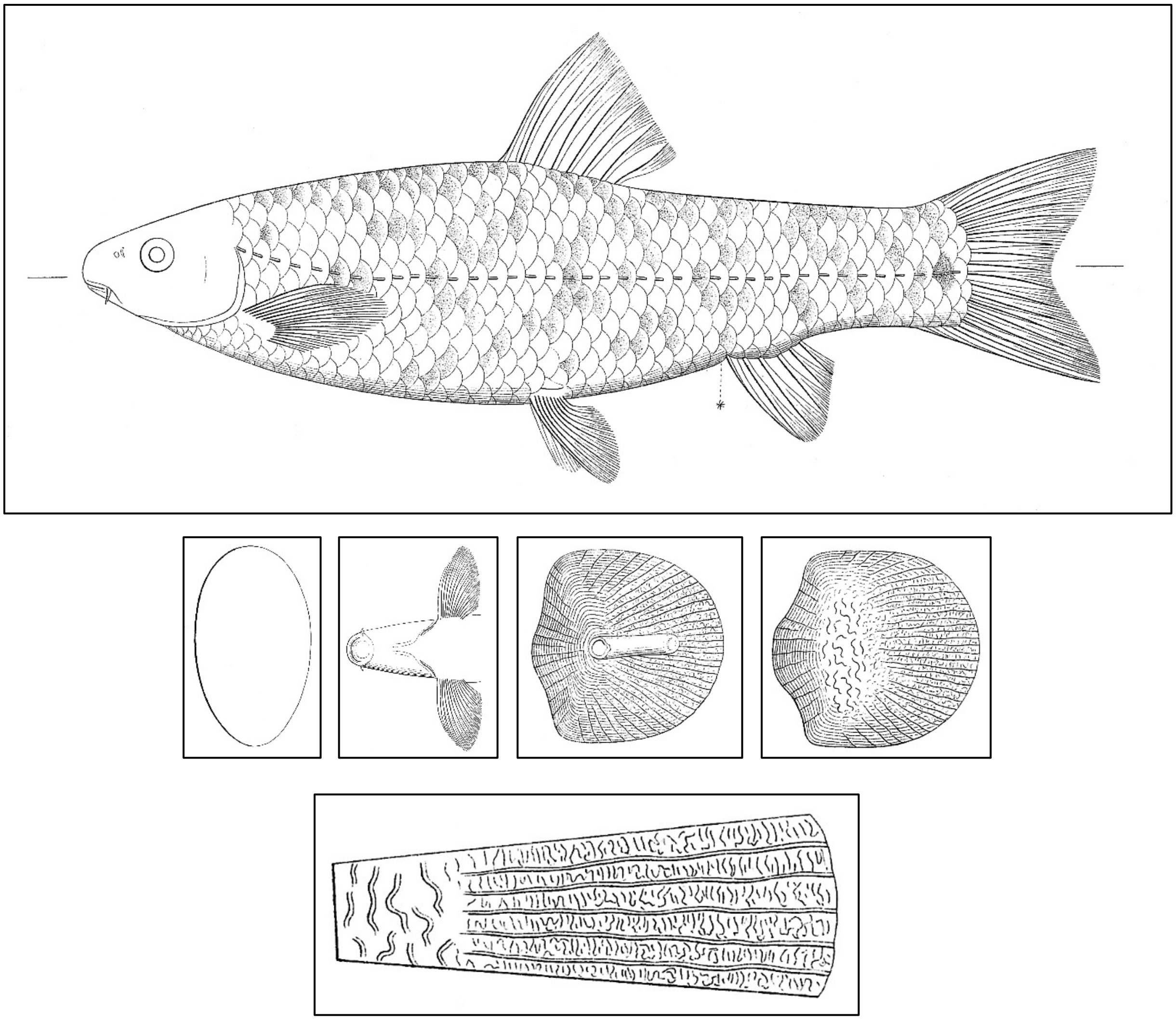
*Garra variabilis*, Turkey, Diyarbakır,
Tigris River, Bismil, Cüneyt Kaya.

**Common names.** See under genus account.

[Gassur diseileki or gassur isivid (gassur meaning colour of strawberries, isivid referring to the spotted, almost black fish according to Heckel (1843b)); karkoor mit-la'oon (from karkur, perhaps related to the root meaning to giggle, and mutalawwin meaning coloured, variable (Mikaili and Shayegh, 2011)), all in Arabic; Gurik and Yapışpkan balık (local names in eastern Turkey) (Kaya *et al*., 2016; Çiçek *et al*., 2020); small-mouth garra, variable garra].

**Systematics.** Menon (1964) considered this species to be the most primitive in the genus. It has been placed in the genus *Discognathichthys* Bleeker, 1860, e.g., by Berg (1949).

Heckel (1843b) gave the type localities as "Mossul" and "Aleppo". The syntypes of *Discognathus variabilis* are in the Naturhistorisches Museum Wien under NMW 53239, 8 specimens, 38-112 mm standard length and in the Senckenberg Museum Frankfurt under SMF 403 (formerly NMW), 4, 72-86 mm standard length, all from Aleppo (Krupp, 1985c). In Vienna I made counts on types as listed below under **Sources**. The *Catalog of Fishes*, downloaded 15 May 2018 listed NMW 53238-40 (3, 8, ca. 10), 53260-69 (1, 2, 2, 2, 3, 2, 2, 2, 2, 2), 53272 (4), SMF 403 [ex NMW] (4), and in the Museum für Naturkunde, Universität Humboldt, Berlin, ZMB 3301 (3) (formerly NMW; 82.6-99.2 mm standard length measured in February 2006). B. Riedel (pers. comm., 11 April 2019) also listed NMW 94707 as a syntype (dry bone, *sic*, probably a dried or stuffed specimen in this case).



*Discognathus variabilis*,
body, cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Discognathus variabilis*, syntypes, NMW 53239, Naturhistorisches Museum, Wien.

*Discognathus variabilis*, syntypes, NMW 53239, Naturhistorisches Museum, Wien.

Cicek *et al*. (2016) compared this species with *Garra rufa* from the Turkish Tigris River using morphometry and attributed the clear differences to feeding habits (benthic in *rufa*) and habitat structure (faster flowing rivers inhabited by *variabilis*). Cıcek *et al*. (2016) found high variation between four localities in the Turkish Tigris River based on morphometric, but not meristic, characters. The variation was attributed to environmental conditions.

**Key characters.** The single pair of maxillary barbels, absence of papillae on the rear part of the adhesive disc, a scaled back, chest and belly, gill raker count, and distribution distinguish this species. It is separated from the closely related, but geographically separated *G. rossica*, by larger size, head length shorter than caudal peduncle length and pectoral fin length,

slightly emarginate caudal fin, and dorsal fin origin closer to snout tip than the caudal fin base (Berg, 1949).

**Morphology.** The body is rounded and can be moderately deep. The predorsal profile is usually convex but can be almost straight. The body is deepest in front of the dorsal fin origin. The caudal peduncle is compressed and deep. The snout is blunt and rounded. The upper lip is not fimbriate at its margin. The structure of the disc and mouth are evident in the photograph above, if correctly identified (the disc is reported as weak without a free anterior margin in the literature). There may be two pairs of barbels in some larger fish. The caudal fin is moderately forked with rounded lobes, especially evident in the lower lobe. The dorsal fin margin is concave. The dorsal fin origin lies anterior to the pelvic fin origin. The depressed dorsal fin does not extend back to the level of the origin of the anal fin. The anal fin margin is concave and the depressed fin does not reach back to the caudal fin base. The pelvic fin is rounded and the fin does not reach back to the anal fin origin. The pectoral fin is rounded and does not reach back to the pelvic fin origin.

Dorsal fin with 2-3, usually 3, unbranched and 6-8, modally 7, branched rays, anal fin with 2-3 unbranched and 5 branched rays, pectoral fin branched rays 11-14, and pelvic fin branched rays 6-8. Lateral line scales 32-40, scales from the dorsal fin origin to the lateral line 4-6, scales below the lateral line to the pelvic fin origin 3-4, scales around the caudal peduncle usually 16, and predorsal scales in mid-line 12-14. Scales are squarish in shape. The anterior margin is crenulated or has a central protrusion. The dorsal and ventral margins are gently rounded and merge into the round posterior margin. The anterior scale corners are abrupt but rounded. Scales have a sub-central anterior focus, fine circuli and radii on the anterior and posterior fields or on all fields. Jawad *et al*. (2017) illustrated a scale. Pharyngeal tooth formula 2,4,5-5,4,2 (2,3,5-5,3,2 in Berg (1949), 3,3,5-5,3,3 in Heckel (1843b)) and the short gill rakers number 13-20, on the lower arm of the gill arch only. Kaya *et al*. (2016) gave 20-26 gill rakers, presumably for the whole arch. The gut is very elongate and coiled (see x-rays above). Total vertebrae number 35(2) or 36(5) based on seven syntypes (one too faint to count) from NMW 53239. The diploid chromosome number was 2n = 102 with karyotype formulae being 42m + 18sm + 24st + 18a (NF = 186) for females and 41m + 18sm + 24t + 19a (NF = 185) for males in fish from Savur Stream, Turkey (Karahan and Ergene, 2010). Durand *et al*. (2002a) gave 2n = 74 listed in Arai (2011).

**Sexual dimorphism.** Specimens from NMW 91121 (see below) had the top and sides of the head finely tuberculate and scales on the back before the dorsal fin with fine tubercles lining the scale margins. The upper lip, lip sides and sucker (except for a naked central area) have keratinised tubercles. Tubercles line the dorsal surface of pectoral fin rays, fading medially and following the ray branching in single rows.

**Colour.** Overall colour is olivaceous brown, dark brown or greyish with darker mottlings. The flanks may have large, irregularly-arranged dark spots. Scales are outlined in black. The upper corner of the operculum may have a black spot. The belly is reddish-yellow. The middle 3-4 rays of the dorsal fin each have a small, black spot at their base. There is a black spot at the caudal fin base and the caudal fin has a dark margin. Dorsal, caudal and anal fin rays are dark. The pelvic and pectoral fins are light with slightly darker rays. The lateral line may occasionally have a double row of black spots as in certain *Alburnoides* spp. Young fish may have a dark lateral stripe. The peritoneum is black.

**Size.** Reaches 15.5 cm or according to Heckel (1843b) 5 Zoll (= about 21 cm).

**Distribution.** This species is found in the Quwayq (= Kueik), Orontes (= Asi) and Nahr

al-Kabir rivers of the Levant and the Tigris-Euphrates basin (Menon, 1964; Krupp, 1985c). In Iran, this species is found in the Tigris River basin where Abdoli (2000) mapped the lower Dez, Jarrahi, Karkheh, middle Karun, lower Kashkan and lower Simareh rivers. However, Jouladeh-Roudbar *et al*. (2020) could not confirm its presence in Iran.

Keyserling (1861) recorded this species from Sistan but this is a misidentification. Records of this species (as *Discognathus variabilis*) from Sistan by Nikol'skii (1899) and Regan (1906) are *G. rossica* (Menon, 1964).

**Zoogeography.** This species is related to *Garra rossica* of eastern Iran. See also under *Garra persica* and the genus Krupp (1985c) considered this species to belong to the Indo-asiatic line of *Garra*.

**Habitat.** This species is found in rivers and streams. *Garra rufa* and this species seem to exclude each other, *variabilis* being more common in faster water (F. Krupp, pers. comm.).

**Age and growth.** Erk'akan *et al*. (2014) found a *b* value of 3.048 in the length-weight relationship for 14 specimens, 9.2-14.5 cm total length, from Diyarbakir, Turkey.

**Food.** Unknown.

**Reproduction.** Unknown.

**Parasites and predators.** None reported from Iran.

**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** This species appears to be relatively rare in Iran and if specific localities are found they should be protected. Listed as of Least Concern by the IUCN (2015).

**Sources.** Type material:- *Discognathus variabilis* (NMW 53260, 53261, 53262, NMW 53263, 53264, 53266, 53267, 53268, 53269, 53272, 53239 and ZMB 3301).

Type material used for counts:- NMW 53260, 1, 40.6 mm standard length, NMW 53261, 2, 87.6-97.8 mm standard length, NMW 53262, 2, 51.4-52.1 mm standard length, NMW 53263, 2, 101.8-103.1 mm standard length, NMW 53264, 3, 52.3-54.2 mm standard length, NMW 53266, 2, 87.6-92.7 mm standard length, NMW 53267, 2, 61.5-68.3 mm standard length, NMW 53268, 7, 43.9- 71.4 mm standard length (dried at some point), NMW 53269, 2, 100.3-109.1 mm standard length, NMW 53272, 4, 84.9-92.1 mm standard length, all previous Tigris at Mosul; NMW 53239, 8, 36.9-111.0 mm standard length, Aleppo.

Iranian material:- None.

Comparative material:- BM(NH) 1935.9.12:27-40, 5, 60.8-69.1 mm standard length, Iraq, Karasu (no other locality data); BM(NH) 1935.9.12:53, 1, 76.0 mm standard length, Iraq, Tchaiy Su (no other locality data); BM(NH) 1986.2.14:2-5, 2, Iraq, Baghdad (33º21'N, 44º25'E); BM(NH) 1968.12.13:290-297, 8, 30.7-71.6 mm standard length, Syria, Tigris River at `Ayn Diwar (37º17'N, 42º11'E); BM(NH) 1968.12.13:298-304, 7, 44.4-66.7 mm standard length, Syria, Quwayq River at Masslemiyeh (no other locality data); NMW 91121, 10, 71.9-115.4 mm standard length, Turkey, Wadi Mahmedian Tschai (ca. 38°20'N, ca. 40°45'E).

## Genus *Luciobarbus*
Heckel, 1843

The species in this genus were formerly placed in the genus *Barbus* Daudin, 1805 (see Bogutskaya and Naseka (2004) and the *Catalog of Fishes* for detailed explanation of authorship of *Barbus*). Over 40 species are found from Spain and North Africa through the Middle East to the Aral Sea basin (Casal López, 2017). There are nine species reported from

Iran.

Fossil evidence from Anatolia extends back to 17.7 MYA and to 19.0 MYA for related *Barbus*. Molecular work suggested divergence of *Barbus* and *Luciobarbus* occurred 27.6 MYA in the late Oligocene and, after a long period of stasis or possibly high extinction, the two genera diversified 19.7 MYA and 18.6 MYA respectively in the early Miocene. *Luciobarbus* (and *Barbus*) are sister to the European *Aulopyge* Heckel, 1841 and together are likely sister to *Cyprinion* and *Schizothorax* (and Chinese *Gymnocypris* Günther, 1868, now a synonym of *Schizopygopsis*) although this needs more work (Gante, 2011).

Machordom and Doadrio (2001) investigated the phylogeography of this former subgenus, full generic status being accorded by Bogutskaya and Naseka (2004). Faddagh *et al*. (2012) used DNA fingerprinting on Iraqi "*Barbus*" cyprinids and found *barbulus, kersin* and *xanthopterus* to form one group (*Luciobarbus*) while *grypus*, *luteus* and *sharpeyi* were divergent from *Luciobarbus*. The genus *Luciobarbus* is paraphyletic as *Capoeta* is placed in it on molecular evidence (Tsigenopoulus *et al*., 2010; Levin *et al*., 2012).

Casal López (2017) found two lineages in this genus, *L*. *mursa* and all other *Luciobarbus* species, splitting about 13.6 MYA in the Middle Miocene, when the eastern Paratethys began to be isolated from the central Paratethys. Other eastern species (and some North African species) diverged in the Upper Miocene around 11 MYA. An initial split was estimated to have occurred around 5.28 MYA in which the Caspian Sea species, *L*. *capito* and *L*. *brachycephalus* (now *L*. *caspius* in the Caspian Sea basin), are the sister group of the rest. Syrian species *L*. *longiceps* and *L*. *pectoralis* from Mediterranean basins in the Near East were clustered together with *L*. *esocinus*, *L*. *xanthopterus* and *L*. *mystaceus* from the Tigris-Euphrates and Persian Gulf basins. Interestingly, two individuals from Iran were found that were not assigned to any recognized species. (*L*. sp. 1 from the Ghareh Aghaj (= Qarah Aqaj) River and *L*. sp. 2 from the Zakhem River (latter locality unclear) - I think these last two are presumably *L*. *barbulus* (Qarah Aqaj) and an unidentified relative as *L*. *barbulus* did not appear in the molecular analysis by Casal López (2017). Another important vicariance event occurred between *L*. *xanthopterus*, *L*. *mystaceus* and the species from Iran, coinciding with the separation of the Tigris-Euphrates and Persian Gulf basins. Both events seem to have occurred close to the Pleistocene period. Results also showed another vicariant event which seem to have occurred during the Messinian Salinity Crisis, in which the Caspian Basin split from the rest of the Eastern Basins.

Casal López (2017) noted that after the first split within the genus *Luciobarbus*, which separated *L*. *mursa* from the rest, a second split gave rise to three clades: Clade I, *L*. *albanicus*, Clade II, mainly Iberian species, and clade III, Eastern and most of the North African species. Within the Eastern subclade, a vicariant event at the end of the Miocene divided the species present in Aral Sea, *L*. *brachycephalus* and *L*. *capito* from the rest. This is in agreement with the isolation of the Caspian Sea since the late Miocene. From the late Miocene to the Pliocene, the basins of the Caspian Sea and Black Sea separated. The separation of the *Luciobarbus* species of the Tigris-Euphrates basin and the Persian Gulf basin (Iranian species being *L*. *xanthopterus, L*. *esocinus*, *L*. *mystaceus*, and *L*. sp. 1 (probably *L*. *barbulus*) and *L*. sp. 2) from the rest of the species in Mediterranean Turkey and the Mediterranean Near East, coincided with the formation in the Pliocene of the Tigris-Euphrates basin when the water from the developing Zagros Mountains drained. The subdivision of the species of the Tigris-Euphrates from the species of the Persian Gulf falls in the Late Pliocene (or close to the Pleistocene - see above).

Valiallahi (2000) described “*Barbus persicus*”, a new species, in his thesis but this has not been formally described. The name may be preoccupied by *Bertinius longiceps persicus* Karaman, 1971.

The genus is characterised by an elongated body, thick anteriorly and laterally compressed posteriorly, with two pairs of barbels, thick, fleshy and papillose lips, sometimes with a median lobe on the lower lip, the absence of papillae on the central part of the lower lip, and by having few and large tubercles on the snout. The mouth is subinferior to inferior. The last dorsal fin unbranched ray is usually thickened (spine-like) and serrated or denticulated. Dorsal fin branched rays are usually 8 and anal fin rays 5. The gut is short to long and can have several coils. These fishes are tetraploid like *Barbus sensu stricto* (Casal López, 2017). The genus is distinguished from *Barbus* mostly by molecular characters.

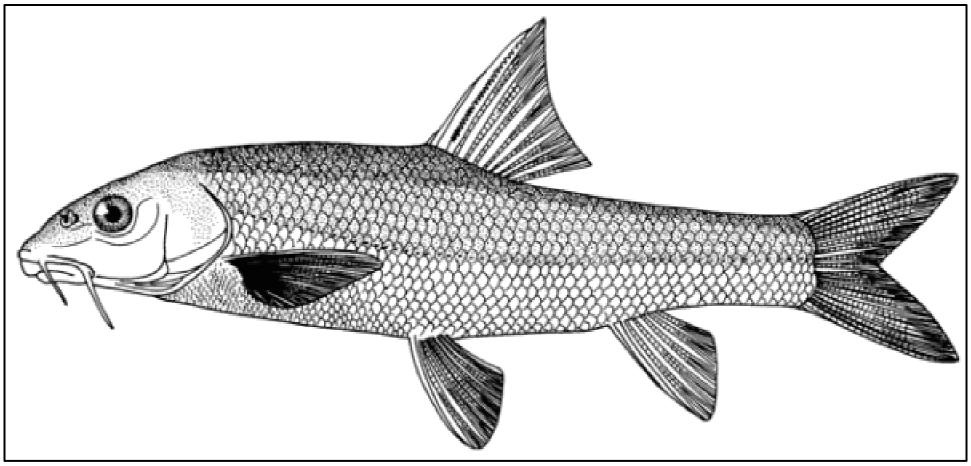
These are medium-sized to very large fishes found in a variety of habitats from lakes to rivers and mountain streams with some found in dams. Females are usually bigger than males, and have longer anal fins, whereas males have longer pelvic fins than females. The species of *Luciobarbus* lay their eggs usually in the gravel bottom of rivers, and the female is usually accompanied by more than one male that will fertilise the eggs. Females use their larger anal fin to excavate nests in the riverbed after an upstream migration.

Seyed Mortezaei *et al*. (2008) gave details of 11 myxozoan and protozoan parasites of “barboid” fishes from rivers, reservoirs and marshes in Khuzestan.

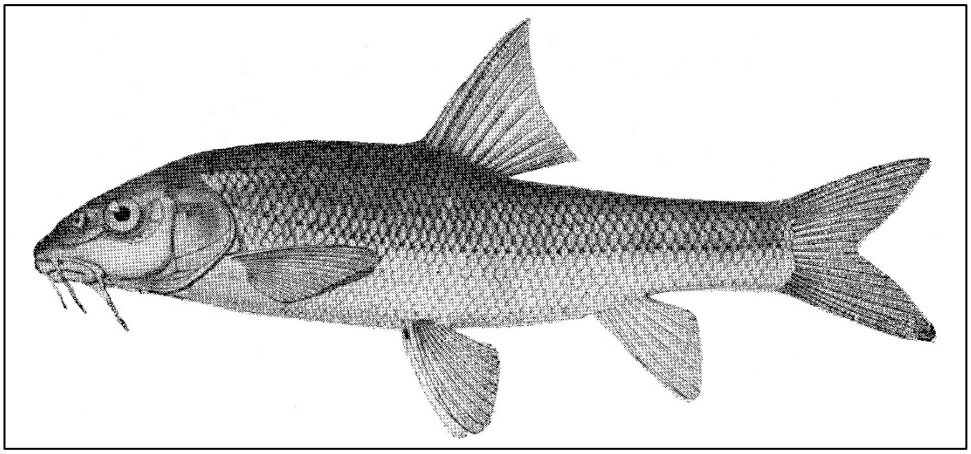
The following table summarises some key distinguishing characters of the Iranian species of *Luciobarbus*.

| Species/ Characters | Modal dorsal fin branched rays | Lateral line scales | Total gill rakers | Lips | Unique morphology | Distribution |
|---|---|---|---|---|---|---|
| *L. barbulus* | 8 | 46-59 | 14-24 | Very fleshy | Large dorsal spine | Hormuz, Kor, Persis, Tigris |
| *L. capito* | 8 | 51-72 | 12-22 | Fleshy | Dark-light flank | Caspian |
| *L. caspius* | 7 | 62-90 | 16-27 | Thin to moderately thick | Predorsal length short | Caspian |
| *L. conocephalus* | 8 | 56-70 | 8-19 | Thin | - | Hari |
| *L. esocinus* | 8 | 62-78 | 8-12 | Thin | Pike-like head | Persis, Tigris |
| *L. kersin* | 8 | 49-58 | 19-23 | Moderately thick | Deep body | Persis, Tigris |
| *L. mursa* | 8 | 74-106 | 7-18 | Thick | Three-lobed lower lip | Caspian, Urmia |
| *L. subquincunciatus* | 8 | 75-88 | 10-13 | Thick, fleshy | Spotted | Tigris |
| *L. xanthopterus* | 8 | 55-69 | 7-14 | Moderately thick | - | Tigris |

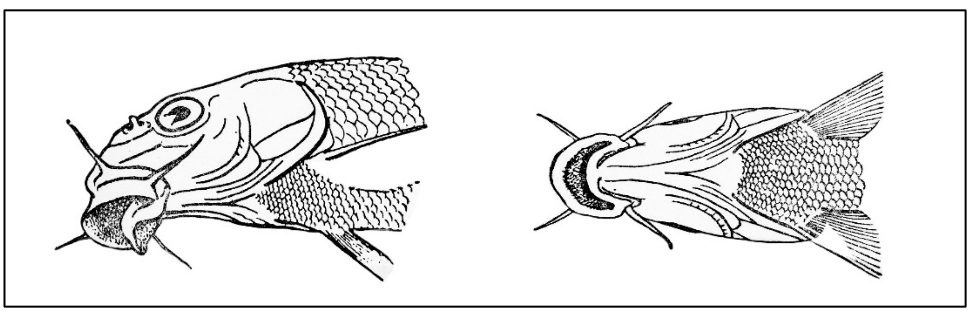
## *Luciobarbus barbulus*
(Heckel, 1847)



*Luciobarbus barbulus*
Susan Laurie-Bourque @ Canadian Museum of Nature.



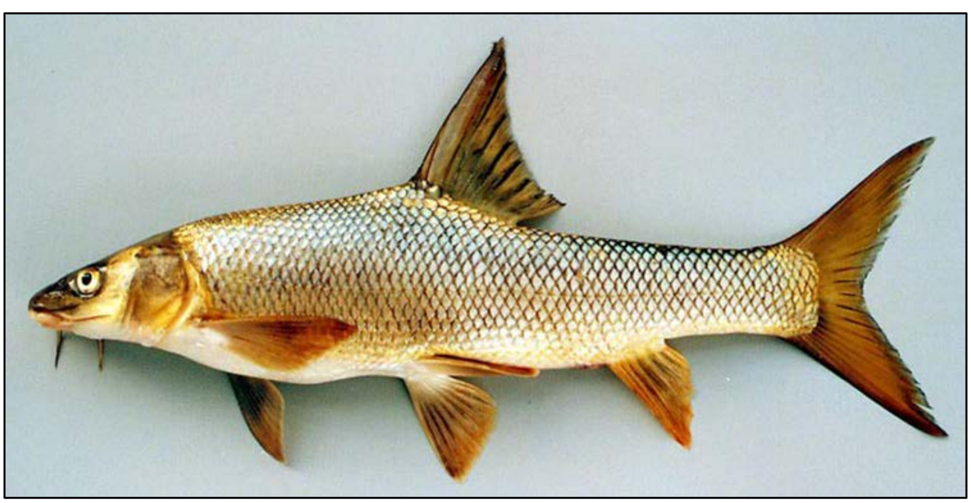
*Luciobarbus barbulus*, 17.0 cm total length, ZISP 24021,
Khuzestan (= Arabistan), Al Khorshir, Karun River basin, after Berg (1949).



*Luciobarbus barbulus*, views of mouth, 17.0 cm total length,
ZISP 24021, Khuzestan (= Arabistan), Al Khorshir, Karun River basin, after Berg (1949).

*Luciobarbus barbulus*, Khuzestan,
variation in mouths, Brian W. Coad.

*Luciobarbus barbulus*, 945.0 mm, Khuzestan, S. A. Mortezavizadeh
(B.barbuls, CC BY 3.0).



*Luciobarbus cf. barbulus*, Syria, Euphrates River, Roland Beck.

**Common names.** Lab pahn (= broad lip), sasmahi-ye lab pahn, berzem or barzam, zard mahi (= yellow fish, presumably in reference to yellowish fins or the lower flank), chaharsool or charsol ( meaning unknown); berzem lab pahn in Khuzestan and Iraq to distinguish it from nominal *L. pectoralis*; boz mahi (= goat fish) or sas or sos mahi in the Dalaki and Shapur River basins (sas and sos meanings unknown but referring to "*Barbus*"); dolenj (= two boats or two fins, Y. Keivany, pers. comm., 25 September 2018).

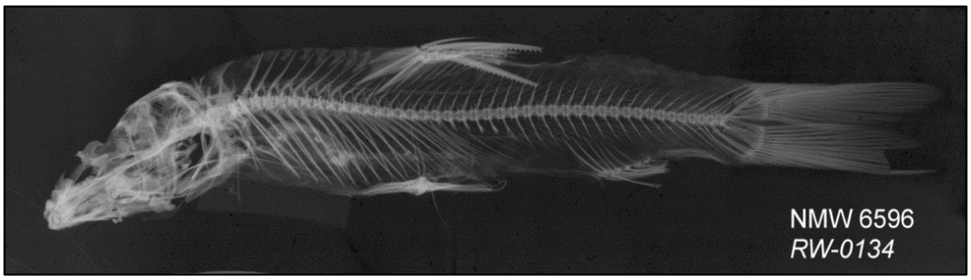
[Abu-barattum, abu baratem, abu bratum (from abu = having and baratim = thick lips) and nabbash (keep digging up, unearthing, in reference to feeding behaviour) (Mikaili and Shayegh, 2011)) in Arabic; Bıyıklı balık in Turkish (Çiçek *et al*., 2020); Qarah Aqaj barbel, Persis barbel].

**Systematics.** Howes (1987) placed this species in his *Barbus sensu stricto*. Karaman (1971) placed it in the synonymy of *Barbus rajanorum* but other authorities considered it to be *Luciobarbus pectoralis* (Heckel, 1843). Almaça (1983) placed this species as a subspecies of *Barbus mystaceus* but later (1984a, 1984b, 1986, 1991) retained *barbulus* as a full species, known only from the Levant, despite Heckel's records from both the Qarah Aqaj (= upper Mond) of Fars, Iran and the Quwayq (= Kueik) River of the Levant. It is separated from *mystaceus* according to Almaça (1983) by having thinner lips, shorter barbels, the last dorsal fin unbranched ray weaker and shorter, more dense denticles spread over a shorter length of ray, higher anal fin, gill rakers less numerous, and the upper dorsal profile is rectilinear and oblique to the back.

The type locality of *Barbus Barbulus* is the "Fluss Kara-Agatsch....bei dem Dorfe Geré" (= Qarah Aqaj or Mond River, Fars; possibly near Kereft, 29°01'N, 52°52'E) and presumably the "Kueik bei Aleppo", the Quwayq River at Aleppo (= Haleb), Syria (Heckel, 1847b). J. Valiallahi, pers. comm., 2001 and Edmondson and Lack (2006) suggested Jereh at 29°15'N, 51°58'E but this is in the Hilleh River drainage, a Dalaki River tributary. In addition, "Geré" takes a hard G in German, not a J. There may be some confusion of names and rivers here. See also under *Alburnus sellal* where Geré could be a separate locality rather than a site on the Qarah Aqaj.

A possible syntype of *barbulus* from the Qarah Aqaj was located by Almaça (1983, 1986) in the Naturhistorisches Museum Wien (NMW 53957) and seen by me but is in too poor condition to be of much value, being mostly bones. Another syntype is listed as NMW 6596 and measures 119.3 mm standard length. In 1997, this was the only syntype recognised and is possibly the same as NMW 53957 re-numbered as the latter was not located in 2002. The catalogue in Vienna listed only one fish, while Heckel's description referred to several fish, so it is not a holotype but a syntype. NMW 6596 is mostly bones and was dried. The fleshy lip fold of the original description could not be discerned, teeth are missing and the dorsal fin is broken off short.

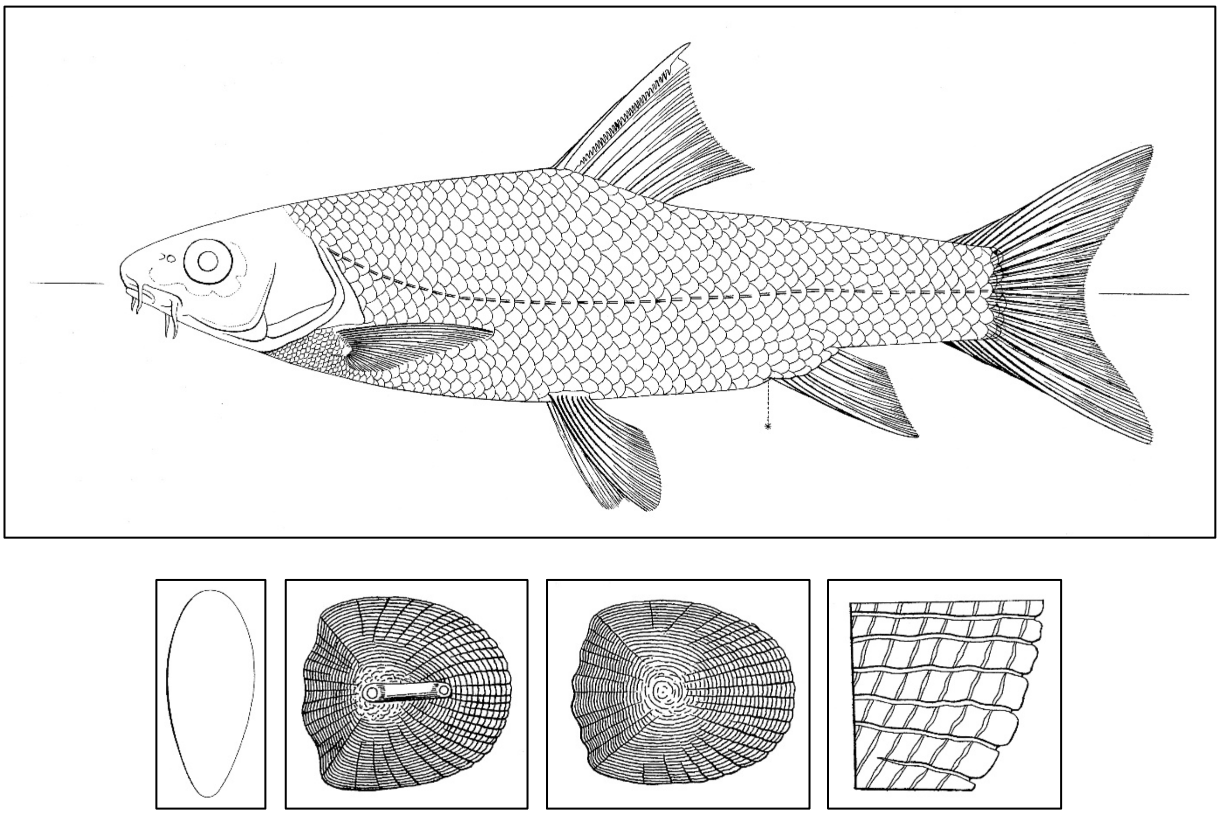
*Barbus barbulus*, syntype, NMW 6596, Naturhistorisches Museum, Wien.



*Barbus barbulus*, syntype, NMW 6596, Naturhistorisches Museum, Wien.

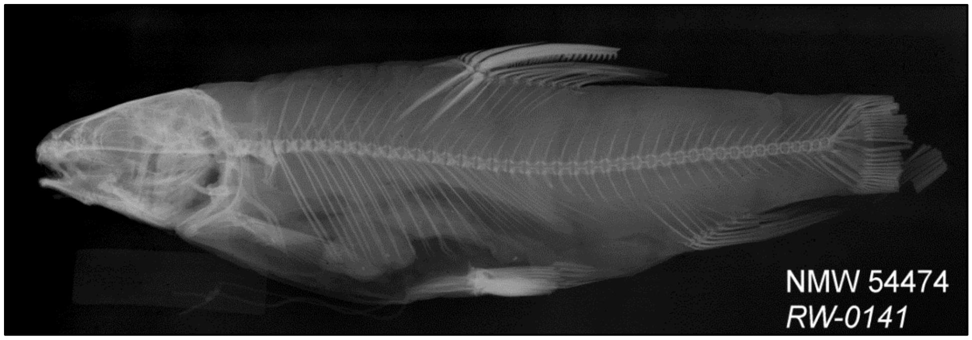
*Luciobarbus pectoralis* (Heckel, 1843) has been identified from Iranian waters by authors but was described, as *Barbus pectoralis*, from the "Orontes" (Heckel, 1843b). The catalogue in Vienna reads "Damascus" (possibly in confusion as this part of the catalogue has been overwritten). The *Catalog of Fishes* (downloaded 27 March 2018) has its distribution as restricted to the Orontes River system in Turkey and Syria, and Mediterranean watersheds of Turkey, and I regarded all records of this species in Iran as probably mis-identifications for *L. barbulus*. Jouladeh-Roudbar *et al*. (2020) checked various Iranian specimens identified as this species by authors, using molecular markers, i.e., COI and cytochrome *b*, but all of them belonged to other species like *L. barbulus*. Types of *L. barbulus* are from both Iran and the Kueik or Quwayq River at Aleppo, Syria, the latter close to the Euphrates River and separate from the Orontes and coastal drainages. The putative holotype of *B. pectoralis* (NMW 54474) was compared with a specimen of similar size from Iran referred to *L. barbulus* (CMNFI 1973-0393). The *L. pectoralis* specimen is partly dried so direct measurement comparisons are not possible. The *L. pectoralis* specimen has more teeth in the dorsal fin spine (27 teeth even though it is broken off, much more than 30 presumably in the intact spine), barbels in *pectoralis* are shorter, the posterior one reaching the anterior half of the eye, the anterior one short of the mouth angle, mouths similar in shape but lips appear to be less fleshy, total gill rakers number 16, lateral line scales number 44, and 4 main row pharyngeal teeth but there is a trace of a fifth tooth not fully ossified, and the total number of vertebrae is 44. Ramin and Doustdar (2017a) compared Iranian material from the Tigris River basin identified as these two species. Most characters overlapped. *L. pectoralis* had median-sized lips as opposed to thick and fleshy lips in *L. barbulus*, total vertebrae were 42-43 in *L. pectoralis* and 40 in *L. barbulus* (this single count suggests limited data for this character), denticles in the dorsal fin spine of *L. pectoralis* were strong and numbered 29-39 denticles and were weaker and numbered 23-32 in *L. barbulus*, and pectoral fin branched rays numbered 18-19 in *L. pectoralis* and 15-16 in *L. barbulus* (the size of fish in each species was not specified and pectoral ray counts may be size-related). Khaefi *et al. (*2017) found that *L. barbulus* had a thicker lower lip, stronger last

dorsal fin unbranched ray with stronger serrations (in contrast to the above), and longer barbels (posterior passing middle of the eye versus not reaching the middle; but almost identical barbel length in head length in Ramin and Doustdar (2017a)) than *L. pectoralis*. The two species are sister groups with a genetic distance of 1.7% (Khaefi *et al.*, 2017). Many of the characters cited above are individually variable within species and distinction and presence of these two *Luciobarbus* in Iran remains uncertain, perhaps to be clarified eventually by DNA work.



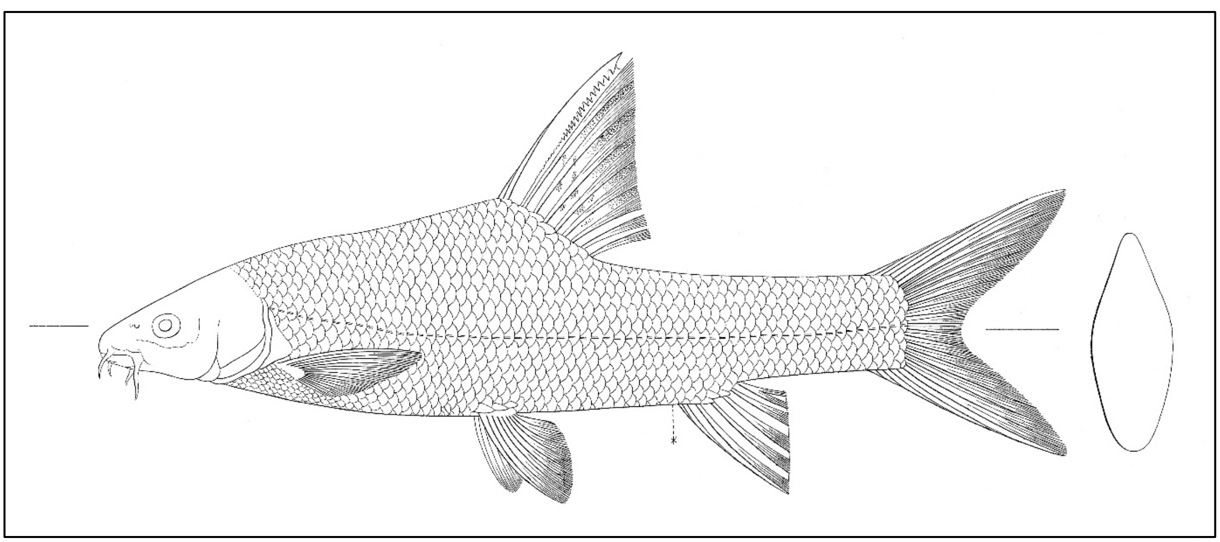
*Barbus pectoralis*,
body, cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

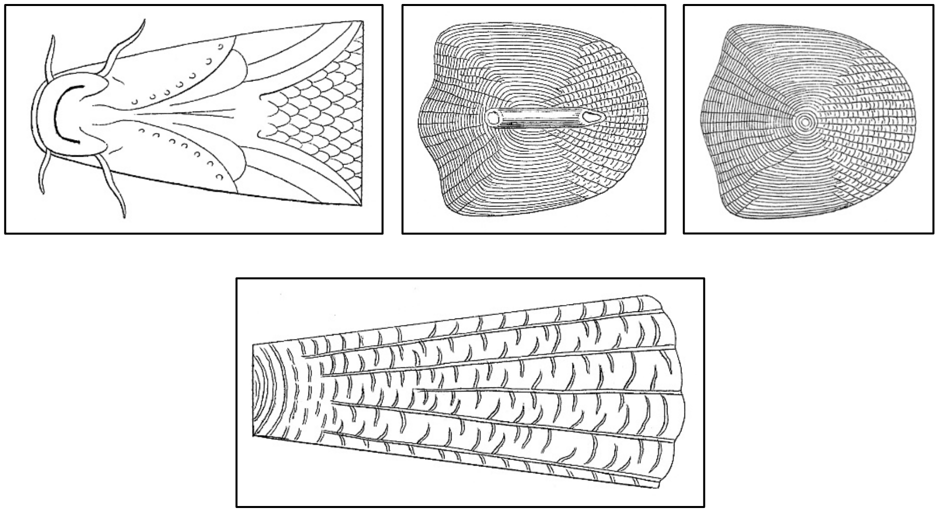
*Barbus pectoralis*, probable holotype, NMW 54474, Naturhistorisches Museum, Wien.



*Barbus pectoralis*, probable holotype, NMW 54474, Naturhistorisches Museum, Wien.

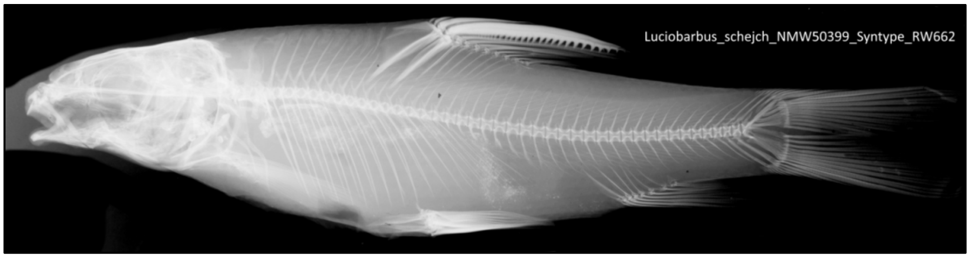
*Luciobarbus Schejch* Heckel, 1843 described from "Mossul" (also spelt *schech* on p. 1019 and p. 1098 in Heckel, presumably in error, and sometimes emended to *scheich*) may be a synonym. It is listed as a synonym of *L. pectoralis* in the *Catalog of Fishes* (downloaded 27 March 2018) but the latter may not occur in the Tigris-Euphrates basin (see below). *Barbus* (= *Luciobarbus*) *schejch* was recognised as a distinct species by Almaça (1983, 1991) but only one specimen, a syntype from the Tigris (in the Naturhistorisches Museum Wien, NMW 50399), was available to him. It measures 136.5 mm standard length. Two other specimens identified as syntypes of this species are under NMW 54520 with standard lengths 175.4 and 270.7 mm. The barbels in the NMW 50399 fish are very short, not reaching the eye and about equal in length while in the other two syntypes the posterior barbel reaches the mid-eye and the barbels are subequal. The lips are fleshy, like *Luciobarbus barbulus,* but there is no central lobe in NMW 50399, present in the smaller of the two other syntypes and poorly developed in the larger. The complete dorsal fin spine bears 29 teeth in the NMW 50399 and 29 or 35 in broken spines of the other two fish. Total gill rakers number 22 in NMW 50399 and 16 or 18 in the other two fish. Lateral line scales number 52 (or 54 to end of scale row on the caudal fin) in the syntype and 57(58) or 58(60). Main row pharyngeal teeth are 4-4 in NMW 50399, missing in the other two fish. These data are somewhat contradictory and further data are required to resolve the status of this nominal species. The catalogue in Vienna listed four fish in spirits and four fish stuffed.





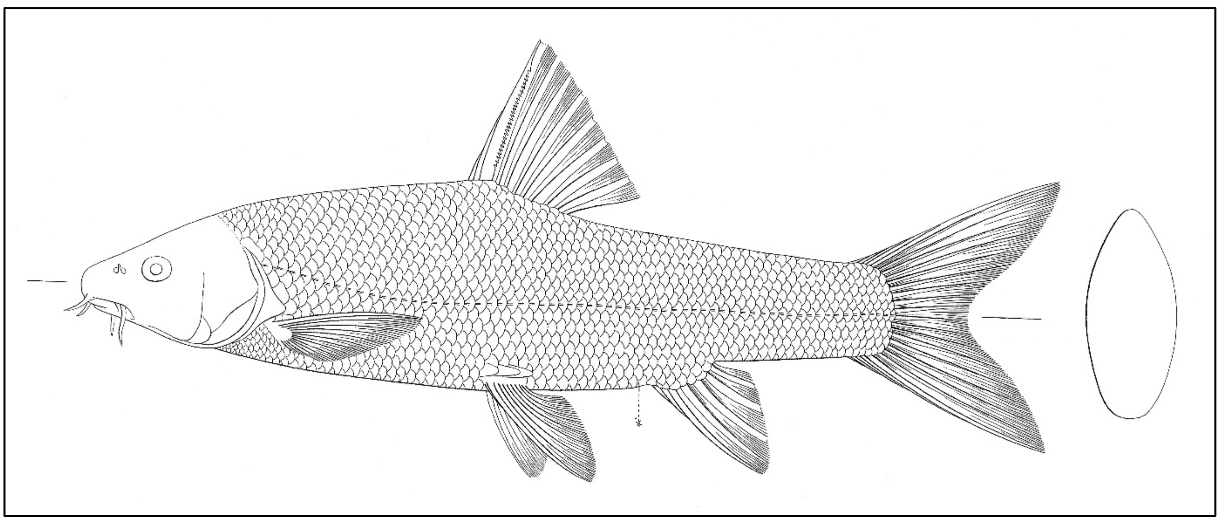
*Luciobarbus schejch*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

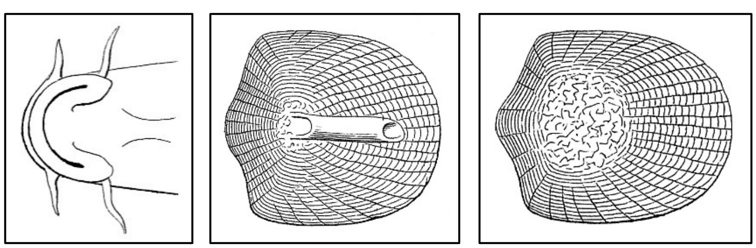

*Luciobarbus schejch*, syntype, NMW50399, Naturhistorisches Museum, Wien.

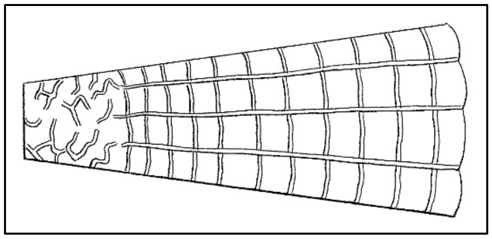


*Luciobarbus schejch*, syntype, NMW50399, Naturhistorisches Museum, Wien.

*L. rajanorum* is a name sometimes used for Iranian *Luciobarbu*s. *Barbus Rajanorum* Heckel, 1843 described from "Aleppo" and later in Heckel (1847a) from "Gewässern von Aleppo" is a hybrid of *L. pectoralis* and *Capoeta damascina* (F. Krupp, *in litt*., 1986) and Almaça (1991) also believed it to be founded on a hybrid; see also Almaça (1983, 1991), Berg (1949) and Karaman (1971) for conflicting views). Valiallahi (2000) also considered this species to be a hybrid, with *pectoralis* or *barbulus*. Almaça (1983) could not find any specimens attributable to *Barbus rajanorum* and the holotype housed in the Naturhistorisches Museum Wien was thought to be lost. However, the type locality for this taxon is "Aleppo" (Heckel (1843b) and Krupp (1985c) stated that the holotype is NMW 54494, 190 mm standard length, Aleppo, 1842, Th. Kotschy). The catalogue in Vienna listed a single specimen and the card catalogue in 1997 listed this fish as the holotype.

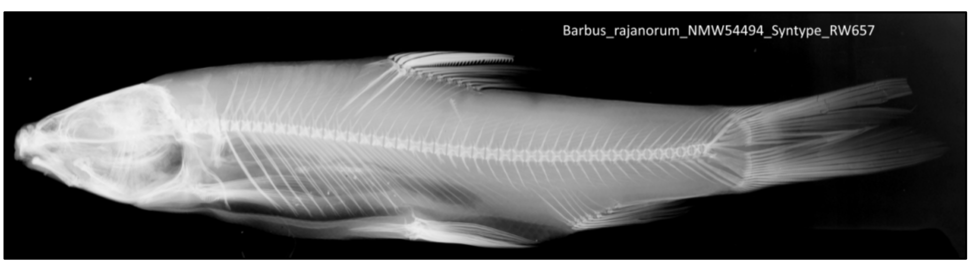






*Barbus rajanorum*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

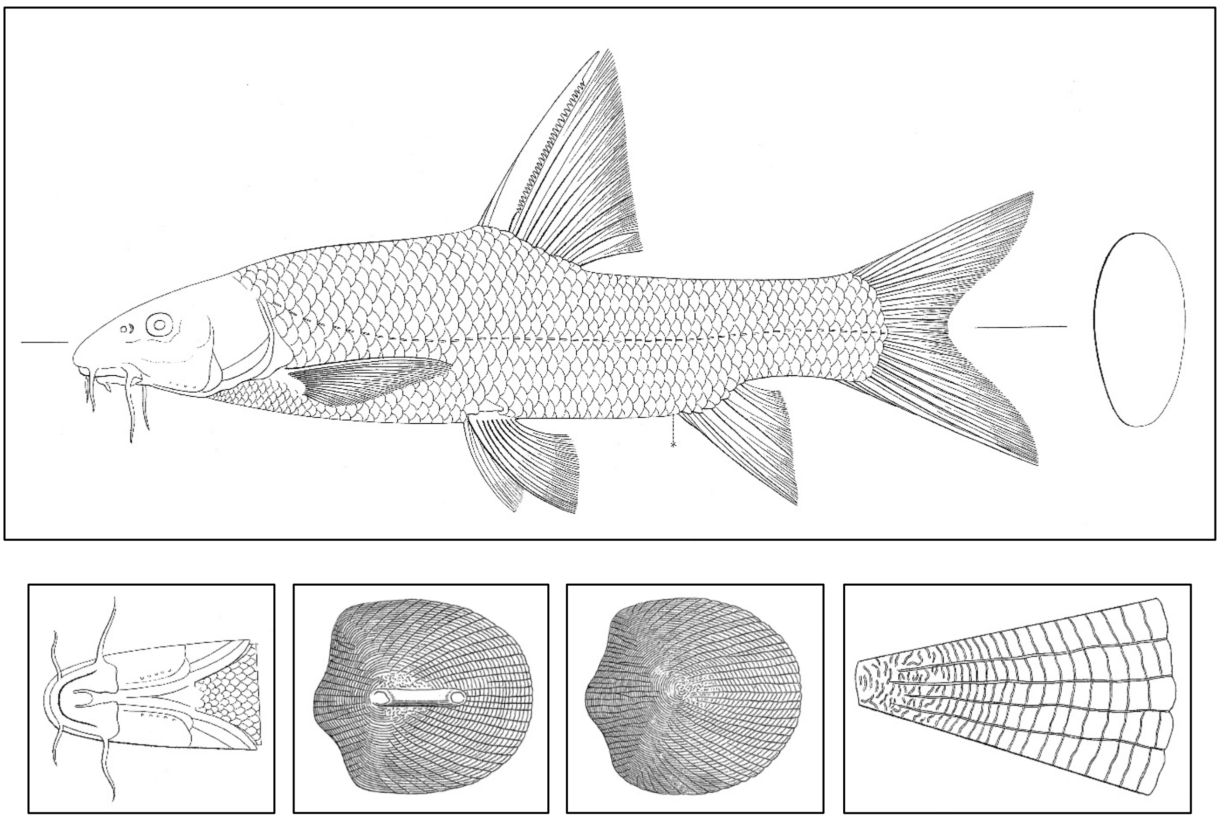

*Barbus rajanorum*, holotype, NMW 54494, Naturhistorisches Museum, Wien.




*Barbus rajanorum*, holotype, NMW 54494, Naturhistorisches Museum, Wien.

I am uncertain as to the identity of *Barbus mystaceus* (Pallas, 1814) reported by Heckel (1843b) from the “Tigris bei Mossul”, Iraq, in regard to Iranian *Luciobarbus* species and do not assign any Iranian specimens collected by me to it. Almaça (1983) recognised *Barbus mystaceus* with two subspecies, *mystaceus* from Aleppo, Tigris at Mosul and the Euphrates, and *barbulus*. Krupp (1985c) placed *Barbus* (= *Luciobarbus*) *barbulus* and Heckel’s *Luciobarbus mystaceus* in *Barbus pectoralis*. F. Krupp (*in litt*., 1987) considered Heckel’s

*mystaceus* to be identical with *B. barbulus* but that Heckel's *mystaceus* differs from that of Pallas, as previously noted by Berg (1949). Berg (1949) pointed out Pallas's *Cyprinus mystaceus* is partly *Barbus* (= *Luciobarbus*) *mursa* and *Barbus* (= *Luciobarbus*) *capito*. Fricke *et al*. (2007) recognised *mystaceus* as a distinct species in the Tigris-Euphrates basin. *Cyprinus mystaceus* Pallas, 1814 was described from Georgian rivers and is most probably a synonym of *Luciobarbus capito* as given by Bogutskaya *et al*. in Bănărescu and Bogutskaya (2003). Heckel's *B. mystaceus* is most probably *B. barbulus*. "Syntypes" of *mystaceus* are in the Naturhistorisches Museum Wien from Mosul on the Tigris River (NMW 16472 (1 specimen), NMW 50394 (2), NMW 54384 (2)) and NMW 54385 (2) but note that authors such as Karaman (1971) and Almaça (1983, 1991) referred the species description to Heckel (1843) in error. These were not marked as being syntypes as observed on a 1997 visit to Vienna.



*Luciobarbus mystaceus*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.

Khaefi *et al*. (2017, 2018) reported on hybrids of *L. barbulus* with *L. kersin* and *L. xanthopterus* in the Iranian Tigris River basin.

**Key characters.** This species is characterised by a serrated and very strong dorsal fin spine similar to that in *Capoeta trutta* in its proportions relative to the body, fleshy lips which may have a median lobe, the fourth major row pharyngeal tooth is molariform, and 46-59 lateral line scales.

**Morphology**. The body is moderately deep and deepest in front of the dorsal fin. The head profile and back in front of the dorsal fin is slightly convex. The caudal peduncle is compressed and relatively deep. The inferior mouth is moderate in size and u-shaped, with

moderate to thick papillose lips and with or without a median lower lip lobe. Some fish have very thick lips so a central lobe is apparent. Some show such a degree of lip development as to appear almost abnormal while fish of similar size or larger lack this hypertrophy. In the latter case, the anterior head may be bluntly rounded and foreshortened rather than having an almost straight upper margin tapering to a pointed end. A snout flap overlaps the upper lip in larger, hypertrophied fish. Larger fish show a groove across the head before the nostrils. Barbels are relatively thin, occasionally quite thick. The anterior barbel does not extend past the anterior eye margin level and the posterior one not past the posterior eye margin in all sizes of fish. Rarely the anterior barbel extends to mid-eye level and the posterior one almost to the anterior operculum margin. The eye is slightly in the anterior half of the head. The dorsal fin margin is rectilinear to slightly concave and oblique to the back. The depressed dorsal fin extends back to before or to the anal fin origin level, apparently independent of size. The dorsal fin origin is over or slightly in front of the origin of the pelvic fin. The last dorsal fin unbranched ray is usually very strong with a moderate density of denticles extending along much of the ray but its strength is variably developed. Khaefi *et al*. (2017) stated denticles cover almost 90% of the ray length and Almaça (1991) 60-90% but in older fish (30-60 cm total length) the ray and its denticles are weaker, the latter covering 33-50% of ray length. The caudal fin has a shallow fork and rounded tips. The anal fin reaches, or not, back to the procurrent caudal fin rays and its margin is straight. The pelvic fin margin is rounded and it extends back almost to the anus. The pectoral fin may or may not extend back to the pelvic fin.

Dorsal fin with 3-4 unbranched and 7-9, usually 8, branched rays, anal fin with 3-4 unbranched and 5 branched rays, pectoral fin branched rays 15-19, and pelvic fin branched rays 8-10, usually 8. Lateral line scales 46-59. Scale shape is squarish with a rounded posterior margin, straight to gently rounded dorsal and ventral margins, and an anterior margin with a slightly protruding central part and shallow to evident indentations above and below it. The anterior corners are evident but rounded. The focus is subcentral anterior to almost central, there are many fine circuli, and numerous radii on all fields, curved in the lateral fields, or not always developed in the lateral fields. A pelvic axillary scale is present but not strongly developed or apparent. Total gill rakers number 14-24, reaching the second raker when appressed. The interior raker surface may be covered with spinules, the internal base is heavily tubercular and the tips may become club-shaped. Pharyngeal teeth are 1 or 2,3,4 or 5-5 or 4,3,2 or 1, hooked at the tip but spoon-like below with the fourth tooth of the inner row molariform, with or without a blunt projection (hooked in small fish) and much larger than the third, and the fifth tooth very small and rounded and sometimes absent apparently independent of size. The gut is elongate and complexly coiled with one anterior and three posterior loops. Total vertebrae number 44-45 (Howes, 1987; Ramin and Doustdar (2017a) gave 40, probably excluding the Weberian apparatus). The syntype of *L. barbulus*, NMW 6596, a syntype of *L. schejch*, NMW 50399, and the holotype of *Barbus rajanorum*, NMW 54494, all have 45 total vertebrae.

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(35), anal fin branched rays 5(35), pectoral fin branched rays 16(1), 17(10), 18(19) or 19(5), pelvic fin branched rays 8(34) or 9(1), lateral line scales 46(1), 47(1), 48(4), 49(7), 50(4), 51(2), 52(8), 53(4), 54(1), 55(-), 56(2) or 57(1), total gill rakers 15(1), 16(1), 17(1), 18(4), 19(7), 20(7), 21(6), 22(4), 23(3) or 24(1), pharyngeal teeth 2,3,5-5,3,2(18), 2,3,5-4,3,2(3), 2,3,4-5,3,2(3), 2,3,5-5,3,1(1) or 2,3,4-4,3,2(1).

**Sexual dimorphism.** Nuptial tubercles are seen on spawning fish in April in the Karun

River (Mortezavizadeh *et al*., 2010).

**Colour.** The back and upper flank are grey to brownish or olive green, the lower flank greenish-golden or yellowish, and the belly whitish, silvery or yellow. The operculum may be greenish. Large fish may be overall silvery with clear, or with dark, fins. In large fish, only the anal fin may show a faint pink tinge but all fins can be yellow to orange, particularly the caudal fin. Barbels are silvery without spots. Upper flank scales are outlined with pigment, and the anterior edge of the dorsal fin and the caudal fin margin are black in preserved fish. The rays and membranes of the fins are speckled with no specific pattern, the dorsal and caudal fins more heavily than the other fins. Small fish have a few spots on the upper to mid-flank or may be profusely speckled in preservative. The iris is silvery. The peritoneum is black.

Small live fish are silvery overall and have pectoral, pelvic, anal and caudal fins yellow to orange to bright red, especially the anal fin and the lower caudal fin lobe. The dorsal fin is grey and the pectoral and pelvic fins yellowish. The operculum is greenish. The lower flank is greenish-golden and the upper flank brown to grey.

**Size.** Reaches 94.0 cm total length and 8.46 kg (Hashemi *et al*., 2010; Mortezavizadeh *et al*., 2010). J. Valiallahi (pers. comm., 2001, 2017a) believed this species reached 1.5 m and 90.0 kg in the Zagros rivers of western Iran.

**Distribution.** This species is found in the Tigris-Euphrates basin, the Orontes and Quwayq rivers, and Persian Gulf basins of Iran. In Iran it is found in the Hormuz, Kor River, Persis and Tigris River basins. In the Hormuz basin it is recorded from the Galehgah (= Galu Gah) and Kul rivers and the Golabi Spring (and possibly in Rudan County in the eastern Hormuz basin identified as *L. kersin*); in the Kor River basin from the Shesh Pir River; in the Persis basin from the Baghan, Dalaki, Dasht-e Palang, Dehram, Dozgah, Fahlian, Helleh, Kheir-Zohreh, Kohmareh Sorkhi, Mond (upper and lower), Qarah Aqaj, Rudbal (= Rudbar), Shapur, Shur, Sorkhi and Zohreh rivers; and in the Tigris River basin the A'la, Alvand, Armand, Bahmanshir, Bazoft, Beshar, Dez, Gamasiab, Gaveh, Haramabad, Harud, Jagiran, Jarrahi (and headwaters), Kahnak, Karkheh, Karun, Kashkan, Khorramabad, Lesser Zab, Marun, Mereg, Nahr-e Shavor, Qaramabad, Qareh Su, Qaveh, Qeshlaq, Qopal, Ramhormoz, Razavar (= Raz Avar), Sezar, Shilaghab, Shur, Simareh, Sirvan, Tang-e Shiv, Yuzi Dar, Zard and Zimakan rivers, the Dez, Karkheh, Kholocheh, Marun, Qeshlaq and Seymarreh dams, and the Hawr Al Azim and Shadegan wetlands (Gh. Izadpanahi, pers. comm., 1995; M. Rabbaniha, pers. comm., 1995; Abdoli, 2000; Ghorbani Chafi, 2000; Izadi, 2000; Eskandari *et al*., 2007; Raissy *et al*., 2010; Teimori *et al*., 2010; Biokani *et al*., 2011; Bahrami Kamangar *et al*., 2012a; Khaksary Mahabady *et al*., 2012; Zareian *et al*., 2012; Biukani *et al*., 2013; Banaee and Naderi, 2014; Khoshnood, 2014; Marammazi *et al*., 2014; Sadeghi Limanjoob *et al*., 2014; Tabiee *et al*., 2014; Esmaeili *et al*., 2015; Shahi *et al*., 2015; Taghavi Niya and Velayatzadeh, 2015; Zamaniannejad *et al*., 2015; Pazira *et al*., 2016; Khaefi *et al*., 2017, 2018; Zamanpoore, 2017; Fatemi *et al*., 2019; Golchin Manshadi *et al*., 2019; Hasankhani *et al*., 2019; Valiallahi, 2020).

**Zoogeography.** Almaça (1991) believed that this species originated from a colonisation wave from South Europe. See also under the genus.

**Habitat.** This species is found in rivers, streams, lakes, dams, marshes and jubes (= irrigation ditches), although found mainly in rivers. van den Eelaart (1954) recorded this species from rivers in Iraq, moving into lakes and marshes on the floods but never far from rivers. Fish from the Karun River (Mortezavizadeh *et al*., 2010) were captured at temperatures ranging from 14.25ºC in February to 28.5ºC in August. Collection data included a temperature range of 9.8-25ºC, pH 6.0-6.5, conductivity 1.9-3.8 mS, river width 1-150 m, slow to fast

current, depth 40-100 cm, clear to cloudy water, mud, sand, gravel, pebble, stone, boulder, bedrock or concrete bottoms, emergent and encrusting vegetation including rushes and filamentous algae, and a grassy or barren shore.

Habitat of *Luciobarbus barbulus* (and *Arabibarbus grypus*, *Barilius mesopotamicus*, *Capoeta trutta*, *Carasobarbus sublimus*, *Cyprinion macrostomus* and *Garra rufa* among cyprinoids), CMNFI 1995-0009A, Khuzestan, A`la River at Pol-e Tighen, Brian W. Coad.

**Age and growth.** Hashemi *et al*. (2010, 2010, 2011) and Hashemi and Mortazavi (2011) examined 812 fish from the southern Karun River in Iran and found a size range of 20-94 cm and 52-4,675 g, growth was isometric, and growth and mortality parameters were $L_\infty$ = 132.9, K = 0.17, $t_0$ = -0.66, M = 0.33, F = 1.04, Z = 2.72 and E = 0.76. Relative yield per recruitment (Y'/R) was 0.021, relative biomass per recruitment (B'/R) was 0.25, exploitation ratio maximum sustainable yield ($E_{max}$) was 0.42, precautionary average target ($F_{opt}$) was 0.16

year$^{-1}$, and limit ($F_{limit}$) as 0.21 year-$^{1}$. The stock was overfished and fishing regulations were required. Mortezavizadeh *et al*. (2010) also examined fish from the Karun River and found a length-weight relationship of $Y = 0.00002L^{2.90}$ for 57 males, $Y = 0.00002L^{3.22}$ for 64 females and $Y = 0.00005L^{2.96}$ for both sexes, indicating isometric growth. The mean size at first sexual maturity ($L_m$) was 38-43 cm for males and 47-52 cm for females. The average length and weight were higher in females than in males. The condition factor was highest in April and the mean value for males was 1.05 and for females 1.31. The male:female sex ratio was 0.83:1 and there was no monthly difference. Valikhani *et al*. (2020) combined fish from the Shadegan Wetland and the Dez and Karkheh rivers and reported a *b* value of 3.16 (isometric growth) and a condition factor of 3.83 for 3 fish (4.1-25.3 cm total length).

Al-Rudainy (2008) gave sexual maturity at 2.8 years, 31.5 cm length and 305 g in Iraq.

**Food.** Diet is benthic organisms including insects. Large plant remains and detritus are also present in gut contents of Iranian fish.

**Reproduction.** Vosoughi *et al*. (2009) examined 236 fish and found spawning in March at Shushtar on the Karun River. The sex ratio was equal. Fifty percent of males matured at 45-50 cm and females at 50-55 cm. First maturity was at 30-35 cm for males and 40-45 cm for females and age was $2^+$ years and $3^+$ years respectively. Fish from the Karun River numbering 210 (Mortezavizadeh *et al*., 2010) had a mean gonadosomatic index (GSI) of 1.58 for males and 1.85 for females. GSI was highest in March for both sexes and lowest in December, indicating spawning in March and April when temperature was about 16ºC. Ghafari and Jamili (2010) sampled 352 fish identified as *L. pectoralis* (probably *L. barbulus*) from the Karun River and found the breeding season was from January to February at 14.3ºC and pH 7.75. Eggs were released in shallow water over gravel or sand in a single batch. Males matured at 3 years with $LM_{50}$ 35-40 cm and females at 4 years with $LM_{50}$ 50-55 cm. Absolute fecundity range was 7,144-332,196 eggs and relative fecundity was 3,845 to 164,753 eggs/kg. Maximum egg diameter was 2.0 mm in February. Sex ratio was 1:2 in favour of females.

Al-Habbib *et al*. (1986) reported spawning during July and August in fish from the Tigris River at Mosul, Iraq. Al-Rudainy (2008) cited a major spawning in April and a lesser one in October in Iraq, with eggs deposited on gravel beds in fast water. Absolute fecundity was about 100,000 eggs.

**Parasites and predators.** Peyghan *et al*. (2001) recorded the cestode *Bothriocephalus* sp. and the nematode *Rhabdocona* sp. from fish from Khorramabad rivers. Mortezaei *et al*. (2007) reported the nematode *Rhabdocona denudata* from this fish identified as *L. pectoralis* (probably *L. barbulus*) in Shadegan Marsh, Khuzestan. Masoumian *et al*. (2008) recorded the myxosporeans *Myxobolus karuni* and *M. persicus* from gills of fish captured in the Karun and Karkheh rivers and Shadegan Marsh. Raissy *et al*. (2010) found ichthyophthiriasis (infection with *Ichthyophthirius multifilis* - ich or white spot disease), which cause epizootics in wild and cultured fishes, in fish from the Armand River in Chahar Mahall and Bakhtiari Province. Raissy and Ansari (2012) also examined fish from the Armand River and found *Ichthyophthirius multifilis* (Ciliophora), *Dactylogyrus akariacus*, *D. lenkorani*, *D. skrjabiensis* and *Gyrodactylus* sp. (Monogenea), *Allocreadium isoporum* and *A. pseudaspii* (Digenea), *Ergasilus* sp., *Lamproglena compacta* and *Lernaea cyprinacea* (Crustacea), *Bothriocephalus gowkongensis* and *Kawia* sp. (Cestoda) and *Rhabdocona denudata* (Nematoda). Peyghan *et al*. (2018) recorded *Ichthyophthirius multifilis* and *Dactylogyrus* sp. from this fish in the Dez River. Moumeni *et al*. (2020) recorded the zoonotics *Anisakis* spp. from fish identified as *L. pectoralis* and probably *L. barbulus* in Iran.

**Economic importance.** This species is a preferred catch of anglers at Ahvaz in Khuzestan, second only to shirbot (*Arabibarbus grypus*). It is caught there on bread or potato bait. Peyghan *et al*. (2001) reported that it is an economically important species with a good market value in the Khorramabad region. Poria *et al*. (2013) noted that it is important as a commercial and sport fish in the Gamasiab River in Kermanshah Province.

**Experimental studies.** Zallaghi *et al*. (2011) found lead and cadmium in liver and muscle tissues of fish identified as *L. pectoralis* (probably *L. barbulus*) from the Karun River at lower and higher levels than recommended by the World Health Organization respectively. Abdi and Alishahi (2014) showed that the pesticide diazinon was toxic to this species and toxicity increased with pesticide concentration. Tabandeh *et al*. (2014) and Mohammadiyan *et al*. (2019) examined tissue distribution and activity of rhodanese, a mitochondrial enzyme that detoxifies cyanide, in fish from the Karun River. This data could then be used to assess severity of cyanide contamination of water or fishes. Tabandeh *et al*. (2014) found mercaptopyruvate sulphur transferase, a cyanide-detoxifying enzyme, in tissues of this species.

Alishahi *et al*. (2013) found that plant extracts of *Echinacea purpurea* (coneflower) and *Viscum album* (mistletoe) but not *Nigella sativa* (fennel flower) had stimulatory effects on growth, resistance against bacterial infection and density stress, comparable with approved chemical immunostimulants.

Hashemipour and Khodadadi (2017) studied the sperm morphology of this species and details of seminal plasma.

Javadzadeh *et al*. (2019) found clove oil had no lasting negative effects on haematological parameters when used as an anaesthetic and no negative effects on the environment and was recommended for fisheries purposes in this species.

**Conservation.** This species appears on fish markets in Khuzestan, is a large species and its habitats are under threat, and thus it may require protection. Pazira *et al*. (2016) did not collect this species in the Helleh River, despite other records, during their 14-month survey from January 2013 to February 2014. Valiallahi (2017a) documented its decline in catches in extensive surveys in western Iran, only 67 fish being caught. Dams preventing migration, pollution and overfishing were cited as factors in the decline of this species. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern as it has a relatively wide range and there is no widespread threat affecting it. Endangered in Turkey (Fricke *et al*., 2007).

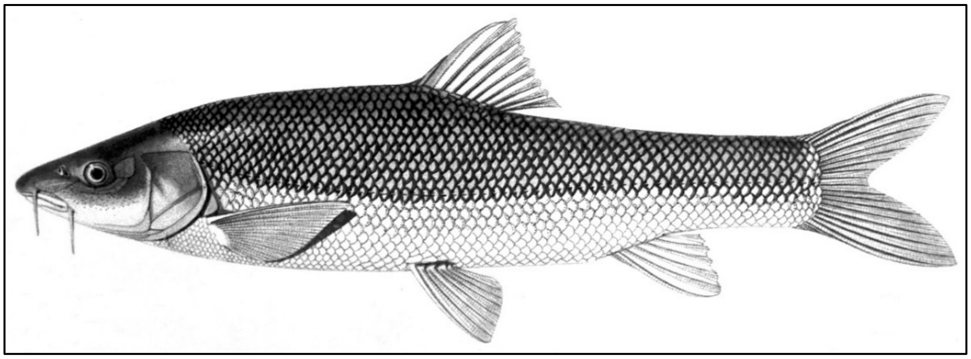
**Sources.** Type material:- *Barbus barbulus* (NMW 6596), and note comments above; *Luciobarbus Schejch* (NMW 50399 and NMW 54520).

Iranian material:- CMNFI 1979-0024, 1, 128.7 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0080, 3, 70.2-231.3 mm standard length, Fars, neighbourhood of Shiraz (no other locality data); CMNFI 1979-0109, 2, 91.1-91.6 mm standard length, Fars, Mond River at Shahr-e Khafr (28º56'N, 53º14'E); CMNFI 1979-0135, 1, 215.4 mm standard length, Fars, tributary to Mond River (28º08'N, 53º10'E); CMNFI 1979-0271, 1, 61.8 mm standard length, Lorestan, river in Kashkan River drainage (33º39'N, 48º32'30"E); CMNFI 1979-0290, 1, 139.1 mm standard length, Kermanshah, river in Qasr-e Shirin (34º31'N, 45º35'E); CMNFI 1979-0293, 1, 210.8 mm standard length, Fars, Mond River at Kavar (29º11'N, 52º41'E); CMNFI 1979-0349, 1, 126.0 mm standard length, Fars, Mond River at Kavar (29º11'N, 52º41'E); CMNFI 1979-0393, 1, 112.1 mm standard length, Khuzestan, Jarrahi River drainage (31º18'N, 49º37'E); CMNFI 1979-0497, 2, 117.4-134.4 mm standard length, Fars, Mond River at Band-e Bahman (29º11'N, 52º40'E); CMNFI 1980-0907, 1, 167.6 mm standard length, Iran (no other locality data); CMNFI 1991-0153, 1,

230.0 mm standard length, Khuzestan, Zohreh River (no other locality data); CMNFI 1991-0154, 2, 272.8-279.6 mm standard length, Khuzestan, Hawr al Azim (ca. 31º45'N, ca. 47º55'E); CMNFI 1995-0009A, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'30"N, 49º53'E); CMNFI 2007-0109, 3, 85.1-138.7 mm standard length, Kordestan, Qeshlaq River basin south of Sanandaj (ca. 35º16'N, ca. 47º01'E); CMNFI 2007-0110, 1, 191.1 mm standard length, Kordestan, Yuzi Dar River basin (ca. 35º05'N, ca. 46º56'E); CMNFI 2007-0111, 1, 153.0 mm standard length, Kermanshah, Alvand River near Sar-e Pol-e Zahab (ca. 34º36'N, ca. 45º56'E); CMNFI 2007-0113, 2, 123.9-139.6 mm standard length, Kermanshah, Razavar River (= Raz Avar), Qareh Su tributary (ca. 34º25'N, ca. 47º01'E); CMNFI 2007-0117, 4, 43.4-155.5 mm standard length, Kermanshah, Gamasiab River near Sahneh (ca. 34º24'N, ca. 47º40'E); CMNFI 2008-0120, 1, 60.4 mm standard length, Khuzestan, Rud Zard at Rud Zard (31º22'N, 49º43'E); CMNFI 2008-0132, 1, 247.1 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); CMNFI 2008-0151, 4, 108.9-189.5 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); CMNFI 2008-0169, not kept, Khuzestan, irrigation ditch in sugar cane fields (31º58'42"N, 48º31'07"E); CMNFI 2008-0171, not kept, Khuzestan, A`la River at Pol-e Tighen (31º23'20"N, 49º52'44"E); CMNFI 2008-0178, not kept, Khuzestan, Karun River at Ahvaz (31º19'N, 48º42'E); CMNFI 2008-0182, 1, 54.6 mm standard length, Chahar Mahall and Bakhtiari, Ab-e Bazoft Sofla (31º38'06"N, 50º28'30"E); CMNFI 2008-0184, 1, 87.4 mm standard length, Chahar Mahall and Bakhtiari, Armand River (31º37'N, 50º47'E); CMNFI 2008-0246, 2, 88.7-141.5 mm standard length, Fars, stream at Sepidan (29º58'19"N, 52º24'04"E); CMNFI 2008-0249, 4, 137.0-180.7 mm standard length, Fars, Qarah Aqaj River near Firuzabad (29º31'03"N, 52º15'E); CMNFI 2008-0260, 1, 157.5 mm standard length, Fars, Zohreh River (no other locality data); ZMH 2515, not measured, Khuzestan, Karun River at Ahvaz (31º19'N, 48º42'E).

Comparative material:- BM(NH) 1920.3.3:23-30, 9, 80.2-98.9 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1931.12.21:4, 172.5 mm standard length, Iraq, Mosul (36º20'N, 43º08'E); BM(NH) 1971.4.2:5, 1, 140.3 mm standard length, Iraq, Tigris near Mosul (36º20'N, 43º08'E); BM(NH) 1972.3.16:2, 69.4 mm standard length, Iraq, 10 km northwest Qala Dize (ca. 36º13'N, ca. 45º05'E); BM(NH) 1974.2.22:1270, 174.6 mm standard length, Iraq, Qizillja River, Lesser Zab (no other locality data); BM(NH) 1974.2.22:1271-1272, 2, 91.9-210.2 mm standard length, Iraq, Siwel River, Tigris River near Kaish Khabour (presumably Faysh Khabur) (ca. 37º08'N, ca. 42º38'E); BM(NH) 1974.2.22:1273-1274, 58.4-62.0 mm standard length, Iraq, Khalis (33º49'N, 44º32'E); BM(NH) 1974.2.22:1275-1277, 3, 182.4-201.0 mm standard length, Iraq, Musharah, Amarah, (31º50'N, 47º09'E); BM(NH) 1974.2.22:1278, 81.9 mm standard length, Iraq, Baghdad (33º21'N, 44º25'E).

## *Luciobarbus capito*
(Güldenstädt, 1773)



*Luciobarbus capito*, ca. 38.8 cm total length, ZISP 13227,
Golestan, Astrabad (= Gorgan) Bay, after Berg (1948-1949).

*Luciobarbus capito*, Aras River, 2 October 1994, Asghar Abdoli.

*Luciobarbus capito*, West Azarbayjan, Aras Dam, March 2012, Keyvan Abbasi.

*Luciobarbus capito*, 0.7 kg, caught on blood worm fished on the bottom,
Zanjan, Qezel Owzan River near Gilvan, April 2010, Sarang Nouripanah.

*Luciobarbus capito*, Gilan, Lakan River (Gohar River), 450.0 mm, 1.0 kg,
25 January 2013, released alive, Sarang Nouripanah.

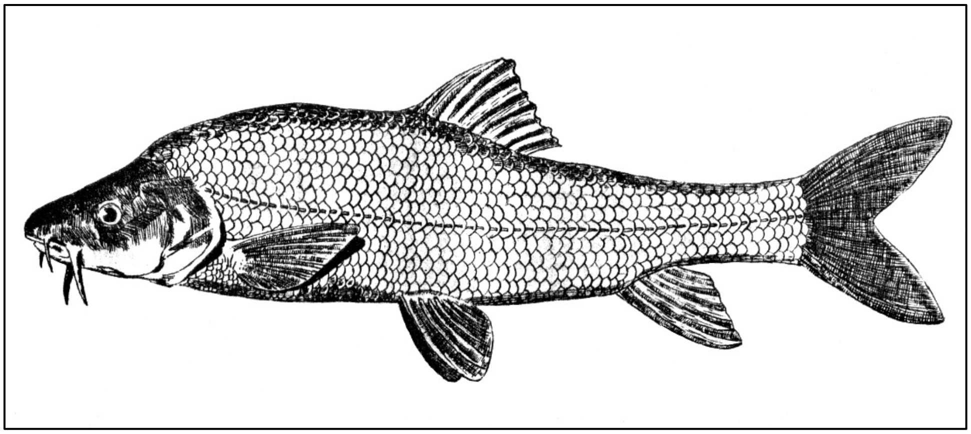
**Common names.** Usach bulatmai (bulatmai = steel fish, see below), usach chanari; zard pareh, zardi, zardek, zardak, zardehpar (in reference to yellow fins); oranj, orenge, orenj or ourange (in reference to orange fins); pulad mahi (= steel fish, from body colour of upper flank, and see variants above and below); sas, sass or sos mahi, ses mahi bozorg (= big fish), sas mahi-e sar bozorg (= big head fish) (sas and its variants being a word of unknown meaning but referring to "*Barbus*").

[Zardapar, shirbit, yastibas zardapar for natio *platycephalus*, all in Azerbaijan; tchanari in Georgian; bulatmai, Hazar tilkiburunu and Bıyıklı balık in Turkish (Kaya *et al*., 2020; Çiçek *et al*., 2020); usach (or usatch) bulatmai and usach chanari in Russian; shir mahi (= milk fish) after Saberi (1998) and possibly zaghara mahi after Ahmadzai (2017) in Afghanistan; bulatmai barbel, great barb].

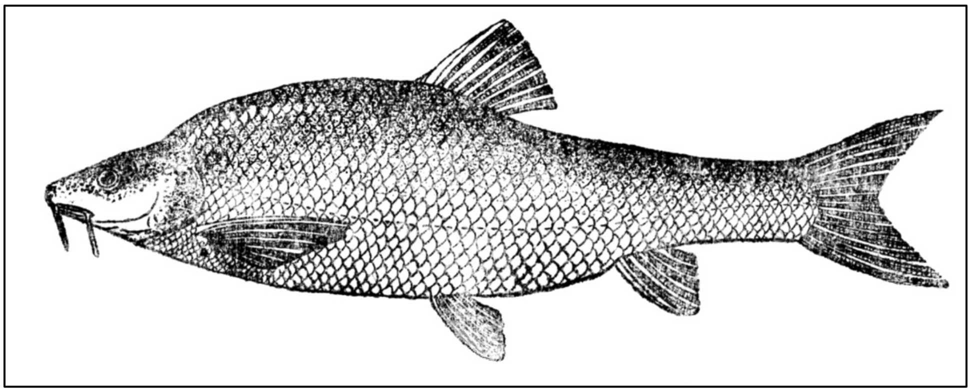
**Systematics.** *Cyprinus capito* was originally described from the Kura River, Transcaucasia. No types are extant.

Howes (1987) placed this species in his *Barbus sensu stricto*. Doadrio (1990) placed it in the subgenus *Luciobarbus* Heckel, 1843 based on a series of osteological characters (listed under *Luciobarbus caspius*).

*Cyprinus bulatmai* Hablizl, 1783 (after Berg (1948-1949) and Rainboth (1981)) was originally described from Enzeli (= Anzali), Iran. *Cyprinus bulatmai* Gmelin, 1784 is not an independent description according to the *Catalog of Fishes* (downloaded 15 November 2015). *Cyprinus chalybeus* Walbaum, 1792 is an unneeded new name for, and objective synonym of, *Cyprinus bulatmai*. *Cyprinus chalybatus* Pallas, 1814 (originally described from Anzali, Iran; sometimes misspelled *chalybeatus*), *Cyprinus mystaceus* Pallas, 1814 (*partim*, from Tiflis), *Barbus lacertoides* Kessler, 1872 described from the Syr-Darya in the neighbourhood of Khodzhent (= Leninabad), Tajikistan, and *Barbus bilkewitschi* Bulgakov, 1923 (originally described from the "Atrek", i.e., the Atrak River in Turkmenistan on the northeastern border of Iran; also spelt *bilkewitchi* on page 236 in Bulgakov but *bilkewitschi* on the plate), are synonyms. These synonyms have no types except for possibly NMW 54235 (2 fish) for *B. lacertoides*. *Barbus capito serratus* Sokolinskii, 1927 is a subspecies from the southern Caspian Sea and *Barbus capito capito* natio *platycephalus* Abdurakhmanov, 1960 is a synonym, a subspecies or a natio in the lower Kura River basin (see Abdurakhmanov (1962) for further details). Berg (1948-1949) and Karaman (1971) considered *Barbus capito serratus* to be a synonym of *B. c. capito*.



*Barbus bilkewitschi*, syntype, after Bulgakov (1929).



*Barbus capito capito* natio *platycephalus*, after Abdurakhmanov (1962).

Bianco and Banarescu (1982) recorded this species from the Hablehrud and the Kul River basin at Darab in Persian Gulf drainages. The two specimens have 52 lateral line scales, 8 dorsal fin branched rays and 18-19 gill rakers. They acknowledge that these two fish have fewer scales than *L. capito* from the Caspian Sea basin but believe they may represent a new subspecies. These fish are presumed to be misidentifications as *L*. *capito* is restricted here to the Caspian Sea basin.

Laloei *et al*. (2003) using the mitochondrial cytochrome *b* gene found no separable populations of this species in 60 samples from the Iranian Caspian Sea coast and rivers. Vali Elahi (2010) found differences in morphological characters in Iranian samples but none were considered sufficient to distinguish taxa. Naderi Jolodar *et al*. (2017) reported two forms in the Iranian Caspian Sea basin, one living in the sea and migrating into fresh water for spawning, and a resident freshwater form.

**Key characters.** The 8 dorsal fin branched rays, the predorsal distance considerably longer than the postdorsal distance distinguishes this species from *L. caspius*, and lack of three lobes on lower lip and the lateral line scale count 51-72 from *L. mursa*, the other Caspian Sea *Luciobarbus*. The clear distinction between upper and lower flanks by pigmentation is also a key character.

**Morphology.** The body is rounded and thick. The head profile is slightly convex, especially in young, sometimes with a groove in front of the nostrils, and may be steep beyond the occiput posteriorly. A nuchal hump may be present. The body is deepest just anterior to the dorsal fin, or midway between the dorsal fin and the occiput. The dorsal profile is straight in

front of and behind the dorsal fin and falls abruptly at the level of the rear of the operculum. There is a rounded keel on the back in front of the dorsal fin. The caudal peduncle is thick and deep. The eye is in the anterior half of the head. The mouth is moderate in size, inferior and horseshoe-shaped. Lips are fleshy and well-developed with tubercles (papillose) but there is no free median lobe on the lower lip, although the lip is thickest at this point. A rostral fold projects over, but does not cover, the upper lip. Barbels can be the most developed in thickness in this species among the *Luciobarbus* considered here but this can vary. The anterior barbel extends back between the anterior eye margin level and its middle and the posterior barbel extends to the posterior eye margin level or almost to the operculum in young and some adults. The dorsal fin margin is slightly concave or emarginate and nearly perpendicular to the back. The depressed dorsal fin does not extend as far back as the anal fin origin level. The dorsal fin origin lies over the pelvic fin origin. The dorsal fin denticles on the last unbranched ray may be lost in very large adults but are evident for two-thirds or more of the spine length in most fish (Karaman, 1971; Almaça, 1981). The last unbranched ray is moderately strong and the denticles are of moderate density along it. Young fish have denticles almost to the spine tip. The caudal fin is moderately to deeply forked with rounded to pointed tips. The anal fin margin is rounded and the fin does not extend back to the base of the caudal fin. The pelvic fin margin is rounded and the fin is remote from the anus. The pectoral fin is emarginate anteriorly and then rounded and does not extend back to the pelvic fin.

Ramin and Dostdar (2015) provided morphometric and meristic data on this species.

Dorsal fin with 3-5, usually 4-5, unbranched rays followed by 7-9, usually 8, branched rays, anal fin with 2-4, usually 3, unbranched and 4-6, usually 5, branched rays, pectoral fin branched rays 15-19, and pelvic fin branched rays 7-9, usually 8. Lateral line scales 51-72 (Karaman (1971) gave 36-70 but he included eight subspecies over a wide range within his definition of the species). There is no obvious pelvic axillary scale although scales in this region are elongate. Scale shape is rectangular horizontally with a protruding and rounded posterior margin, gently rounded to straight dorsal and ventral margins and an anterior margin that is rounded, wavy, or protruding centrally with an indentation above and below. The anterior corners are rounded but distinct. The scale focus is slightly subcentral anterior, there are numerous fine circuli, and there are radii on all fields with those on the lateral fields few and often curved. Total gill rakers number 12-19, rarely to 22, increasing in number with the size of the fish, reaching the one below or slightly further when appressed, with a rounded and knobbed tip, and a large internal rounded extension. Pharyngeal teeth are usually 2,3,5-5,3,2 with minor variants such as 2,3,5-5,3,1, 2,3,4-5,3,2, 2,3,5-4,3,2, 2,3,5-5,2,1, 2,2,5-5,3,2 or even 1,2,3-3,2,1, hooked and spoon-like below with the depression below the crown filled in, the fourth one in the inner row the largest and pointed or blunt and rounded, the fifth smaller and blunt. The gut is long and complexly coiled, with several anterior and posterior loops. Total vertebrae number 42-45 (Howes, 1987 - presumably excluding the four Weberian vertebrae), 45-47 (Elanidze, 1983), 43-49 (Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003 - some counts may lack the Weberian vertebrae). Chromosome number 2n = 100, NF = 172 (Pourali Darestani *et al*., 2006).

Meristic values for Iranian specimens are:- dorsal fin branched rays 7(1) or 8(49), anal fin branched rays 5(50), pectoral fin branched rays 16(3), 17(27), 18(18) or 19(2), pelvic fin branched rays 7(2) or 8(48), lateral line scales 53(3), 54(4), 55(7), 56(10), 57(6), 58(7), 59(7), 60(5) or 61(1), total gill rakers 13(3), 14(15), 15(18), 16(9), 17(4) or 18(1), pharyngeal teeth 2,3,5-5,3,2(33), 2,3,5-5,3,1(1), 2,3,4-5,3,2(2), 2,3,5-4,3,2(1), 2,3,5-5,2,1(1) or 2,2,5-5,3,2(1),

and total vertebrae 46(28), 47(37) or 48(3).

**Sexual dimorphism.** Apparently, there is no spawning colouration or breeding tubercles.

**Colour.** The upper flank and head are steel-grey (hence bulat mahi) and the lower flank and belly are a strongly contrasting pale yellow or pearly-white. Occasionally fish with a uniform colouration are found and preserved material may be uniform. The steel-grey upper flank may be comprised of dark scale margins surrounding a silvery-grey scale centre. The lateral line may be darkly pigmented. Spots may occur individually on the body. The iris is silvery with a grey exterior ring and a very narrow interior golden ring. Barbels are white with grey on the inner surface. The dorsal fin is greyish and may have some dark grey spots. The caudal fin has a greyish, yellowish or slightly orange upper lobe, sometimes with faint dark grey spots, a more strongly coloured and larger yellow-orange to canary-yellow lower lobe and pink margins. The whole caudal fin may be dark reddish. The pectoral fin is whitish with a little or a considerable amount of pink or yellow. The pelvic and anal fins are canary-yellow to orange with a white margin. Young fish may be darkly speckled and mottled on the mid and upper flank rather like *Barbus cyri*. The peritoneum is dark brown.

**Size.** Reaches 1.08 m and 16.0 kg. A specimen from the Sardab River was 85.0 cm and 5.5 kg (A. Abdoli, pers. comm., 1995) and the largest average length and weight for 180 fish from the Tajan River were 85.0 cm and 5.8 kg (Naderi Jolodar *et al*., 2017).

**Distribution.** This species is found in the basins of the Caspian and Aral seas. Karaman (1971) gave a distribution from the Iberian Peninsula and North Africa to Southwest Asia but he included eight subspecies within his definition of “*Barbus*” *capito*.

In Iran, this species is found in the whole Caspian Sea basin, including the Ahar, Alamut, Aras, Atrak, Babol, Chalus, Dogh, Ghotor, Gohar, Gorgan, Haraz, Harisak, Lakan, Larim, Lavij, Lisar, Mars, Masuleh, Pir Bazar, Polrud (= Pol-e Rud), Qezel Owzan, Pasikhan, Rasteh, Sardab, Sefid, Shafa, Shah, Shalman, Sheikan, Shirud, Siah, Siah Darvishan, Sowsar, Tajan, Talar, Taleghan (= Taleqan), Tonekabon, Valam, Zangbar and Zarem rivers, the Aras Dam, the Nazdik, Sefid and Zire dams on the Sefid River, the Sattarkhan Dam on the Ahar Chay, East Azarbayjan, the Shahid Rajaei Dam on the Tajan River, the Voshmgir Dam on the Gorgan River, the Anzali Talab and its mouth, the Fereydun Kenar International Wetland, Valasht Lake, and the along the sea coast (Derzhavin, 1934; Bianco and Banarescu, 1982; Almaça 1984a; Aliev *et al*., 1988; Holčík and Oláh, 1992; Kiabi *et al*., 1994; Karimpour, 1998; Abbasi *et al*., 1999, 2007, 2017; Kiabi *et al*., 1999; Abdoli, 2000; Pazooki *et al*., 2003; Masoumian, 2007; Aghili *et al*., 2008; Miar *et al*., 2008; Abdoli and Naderi, 2009; Hajirostamloo, 2009; Kazemian *et al*., 2009; Ahmadpour *et al*., 2012; Rahmani *et al*., 2013; Abdoli *et al*., 2014; Rustami *et al*., 2018; Shahnazari *et al*., 2020; Aazami and Alavi Yeganeh, 2021; and see photographs above).

Valiallahi (2000) considered this species to be present in western Iran, in the Tigris River basin and Reyahi-Khoram *et al*. (2014) recorded this species from the Dinvar and Razavar (= Raz Avar) rivers near Bisotun in the Tigris River basin, presumably misidentifications.

Jouladeh-Roudbar *et al*. (2020) recorded this species from the Jaj River in the Namak Lake basin as a translocation.

**Zoogeography.** Almaça (1984b) considered this species to be a Sarmatian Sea remnant, a Neogene brackish-water basin, and related to Euro-Mediterranean “*Barbus*”. See also under the genus.

**Habitat.** This species is found in rivers, streams, canals, lakes, dams, lagoons and brackish environments. This species avoided muddy bottoms (Solak, 1977) although Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya (2003) reported that it preferred warm, deep, slowly-flowing water above gravel, sand or mud and can be found in lacustrine habitats. Spawning migrations in the Kura River of Azerbaijan went as far up as Aragva and generally it ascended to the uppermost tributaries of rivers it entered. The spawning run in the Kura lasted almost the whole year except for the two coldest months. However, the main spawning runs were in September-October and April (Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003). The Caspian Sea form is anadromous but there are also resident forms in the rivers there. Knipovich (1921) reported this species at depths of 9.15-14.2 m, possibly deeper, in the Iranian Caspian Sea. It has been caught at 31-32°C in the Sefid River estuary on 9 July 1962 (CMNFI 1970-0565, CMNFI 1980-0908). There are both resident and anadromous populations in the Anzali Lagoon (Karimpour, 1998). Radkhah *et al*. (2021) noted suitable sites for spawning and reproduction included rubble beds in rivers with high-velocity flow and a temperature of about 22°C.

**Age and growth.** Shajie (2003) and Shajiee *et al*. (2002) for 207 fish found a male:female sex ratio of 3:1 in the Caspian Sea off Gilan and a life span of 8 years. The highest length and weight growth were in years 1 and 2. Gonadosomatic and hepatosomatic indices, length-weight relationships and other growth and fecundity indices were given. The gonadosomatic index was highest in June and July, at spawning, and lowest in November and December. Amouei *et al*. (2013) found a maximum age of $4^+$ years and total length of 38.6 cm in fish caught by artisanal fishermen in the southern Caspian Sea of Iran. Mean length was 23.38 cm, male:female sex ratio was 1:1.07 with no significant difference, and length-weight relationship was $W = 0.004TL^{3.179}$. Aazami *et al*. (2015b) gave a *b* value of 2.99 for 94 fish, 3.18-8.09 cm total length, from the Tajan River. Naderi Jolodar *et al*. (2017, 2018) examined 180 fish, 14.0-85.0 cm total length, from the Shahid Rajaei Dam on the Tajan River, and found male and female mean length and weight were significantly different, the overall *b* value was 2.888 indicating negative allometric growth (males 2.225 and females 2.883), the male:female sex ratio was 1.14:1, the von Bertalanffy growth equation was $L_t = 138.6[1\text{-}^{e\text{-}0.1(t+0.2)}]$, and fish lived up to $9^+$ years. Mouludi-Saleh *et al*. (2021) examined 207 fish, 7.5-84.5 cm total length, from the Sefid River and Gilan coast and recorded a *b* value of 2.99, isometric growth, and a condition factor of 1.01.

Solak (1989c) examined a population of this species in the Aras River in Turkey and found a life span of over 4 years. In the Caspian Sea basin generally, fish may live up to 8 years (Abdurakhmanov, 1962; Eagderi *et al*., 2013). Anadromous fish were heavier than fish of the same length that were river residents. Maturity was attained at 3-5 years with females mature one year later than males. Spring migrants spawned that summer while summer or autumn migrants overwintered to spawn the following spring or summer (Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003).

**Food.** Stomach contents consisted of insects, crustaceans and worms, and filamentous algae and other plant material with associated invertebrates. Terrestrial insects, small fishes and frogs were also taken. Abdoli (2000) reported Ephemeroptera, Trichoptera and Chironomidae. Abdurakhmanov (1962) reported grasshoppers and ants, presumably taken at the surface, in Azerbaijan. Naderi Jolodar *et al*. (2017, 2018) found the diet of fish from the Shahid Rajaei Dam on the Tajan River was herbivorous before puberty (under 4 years of age) tending to omnivory, and later carnivory. Food items were oligochaetes, macrophytes,

nematodes, crustaceans, *Carassius gibelio*, chironomids, coleopterans and plants, with *Carassius* and plants being the most abundant.

**Reproduction.** A fish, 19.2 cm standard length, with well-developed testes was caught in the Gorgan River on 7 July 1978 (CMNFI 1979-0491), suggesting a spawning season of late spring and summer, agreeing with egg diameters of fish from Azerbaijan which are largest in June.

Shajie (2003) examined fish in the Caspian Sea off Gilan and found spawning occurred in June-July, spawning was asynchronous, and maturity was at 3-4 years for males and 4-5 years for females. Eagderi *et al*. (2006) studied the reproductive cycle in male fish migrating to the Sefid and Polrud (= Pol-e Rud) rivers. Spermatogenesis developed rapidly from late March with the process continuing up to July. Eagderi *et al*. (2013) described ovarian follicle maturation in migratory females from the Sefid and Polrud (= Pol-e Rud) rivers. This process began in early May when matured oocytes were spawned or degenerated, development continued through summer and early fall, a dormant period was entered in late fall and winter, and restarted the following spring with rising water temperatures. The species had long spawning period and was a batch spawner. Females spawned for the first time at 5 years and males at 4 years of age.

Eggs numbered up to 193,600 and diameters up to 1.8 mm in Azerbaijan (Abdurakhmanov, 1962), or as much as 3.0 mm, presumably after swelling (Salikhov *et al*., 2001).

**Parasites and predators.** Molnár and Jalali (1992) recorded the monogenean *Dactylogyrus linstowi* from this species in the Sefid River. Masoumian and Pazooki (1998) surveyed myxosporeans in this species in Gilan and Mazandaran provinces, finding *Myxobolus musculi*. Sattari *et al*. (2002) and Sattari (2004) recorded the presence of the nematode, *Eustrongyloides excisus*, in the body cavity. This parasite could damage muscles in commercial species and render them unsuitable for sale. Masoumian *et al*. (2003) recorded *Myxobolus musculi* while Pazooki *et al*. (2003) recorded *Rhabdochona hellichi*, *Paradiplozoon homoion* and *Pseudocapillaria tomentosa*, all reports from fishes captured in the Tajan and Zarem rivers of Mazandaran. Sattari *et al*. (2004, 2005) surveyed this species in the inshore area of the Caspian Sea, recording *Eustrongyloides excisus* and *Anisakis* sp. Masoumian *et al*. (2005) recorded the protozoan parasites *Ichthyophthirius multifilis* and *Trichodina perforata* from this species in water bodies in West Azarbayjan. Masoumian (2007) reported the parasite *Trichodina perforata* from fish in the Aras, Ghotor and Zangbar rivers in West Azarbayjan. Pazooki *et al*. (2007) recorded various parasites from localities in West Azarbayjan Province, including *Neoechinorhynchus rutili*. Miar *et al*. (2008) examined fish in Valasht Lake and the Chalus River, Mazandaran and found the metazoan *Bothriocephalus gowkongensis*. Sattari *et al*. (2008) reported the nematode *Eustrongyloides excisus* and the trematode *Asymphyllodora tincae* from fish along the southern Caspian Sea shore.

**Economic importance.** Holčík and Oláh (1992) reported a catch of only 9.0 kg in the Anzali Talab for 1990. This species had a catch of 17 t in 1997, 28 t in 1998 and 7 t in 1999 during the 6-month Caspian beach seine fishing season (October to April). For the years 1998 and 1999, 138 beach seines were used 51,000 times (M. Ramin, pers. comm., 2000). It no longer appears in annual fishing reports of the Iranian Caspian Sea (Eagderi *et al*., 2013). In East Azarbayjan it reaches sizes large enough for sport fishing and as a commercial species (Ghasemi, 2002).

This species was of minor importance commercially in the former U.S.S.R. and is a

sport fish in Georgia (Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003).

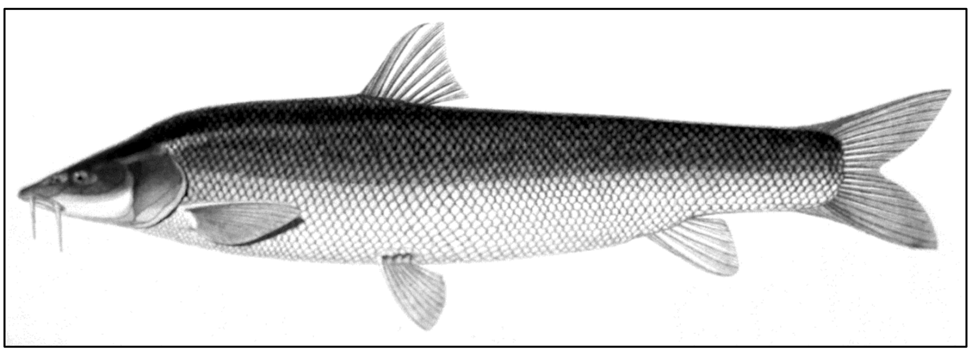
**Experimental studies.** Solgi *et al*. (2019) found iron to have the highest metal content in fish from Manjil Dam, the highest levels of zinc and iron were in the gills and the lowest in the muscle, the reverse was true for copper, and copper and zinc levels were lower than international standards while iron was low to high depending on the standard used.

**Conservation.** Kiabi *et al*. (1999) considered this species to be conservation dependent in the south Caspian Sea basin according to IUCN criteria. Criteria included commercial fishing, sport fishing, medium in numbers, habitat destruction, widespread range (75% of water bodies), absent in other water bodies in Iran, and present outside the Caspian Sea basin. Mostafavi (2007) listed it as conservation dependent in the Talar River, Mazandaran. Naderi Jolodar *et al*. (2017) reported it to be in serious danger of extinction in Iran but the Shahid Rajaei Dam on the Tajan River served as a genetic storage. However, Sharghi *et al*. (2011) found only a single specimen of *Luciobarbus capito* in over a year of sampling (2008-2009) above and below this dam. Radkhah *et al*. (2021) reported that the Iranian Fisheries Organization implemented artificial and semi-artificial propagation projects for this species in 2002 using hormonal treatments such as HCG, P.G and LHRa, but this attempt was not successful. Reported as Vulnerable in Turkey (Fricke *et al*., 2007) and listed as Vulnerable by the IUCN (2015). An attempt at artificial and semi-artificial propagation in Iran was unsuccessful (Eagderi *et al*., 2013).

**Sources.** Iranian material:- CMNFI 1970-0509, 2, not kept, Gilan, Sefid River at Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1970-0521, 7, 32.7-102.5 mm standard length, Gilan, Sefid River near Lulaman (no other locality data); CMNFI 1970-0525, 5, 111.9-133.4 mm standard length, Gilan, Sefid River near Mohsenabad (ca. 37º22'N, ca. 49º57'E); CMNFI 1970-0526, 19, 33.9-52.9 mm standard length, Gilan, Sefid River below Astaneh Bridge (37º19'N, 49º57'30"E); CMNFI 1970-0528, 3, not kept, Mazandaran, Tajan River estuary (36º49'N, 53º06'30"E); CMNFI 1970-0531, 1, 157.3 mm standard length, Mazandaran, Larim River talab (36º46'N, 52º58'E); CMNFI 1970-0536, 1, 194.4 mm standard length, Gilan, Siah River estuary near Rudbar (36º53'N, 49º32'E); CMNFI 1970-0538, 10, 36.7-188.5 mm standard length, Gilan, Qezel Owzan River above Manjil Dam (36º44'N, 49º24'E); CMNFI 1970-0543A, 1, 170.4 mm standard length, Gilan, Caspian Sea at Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1970-0546, 10, 39.3-61.8 mm standard length, Gilan, Sefid River canal (no other locality data); CMNFI 1970-0553, 1, 58.1 mm standard length, Gilan, Sowsar Roga River (37º27'N, 49º30'E); CMNFI 1970-0563, 1, 70.1 mm standard length, Gilan, Caspian Sea at Kazian Beach (ca. 37º29'N, ca. 49º29'E); CMNFI 1970-0565, 7, not kept, Gilan, Sefid River estuary (ca. 37º28'N, ca. 49º54'E); CMNFI 1970-0568, 8, 62.5-132.0 mm standard length, Gilan, Caspian Sea at Kazian Beach (ca. 37º29'N, ca. 49º29'E); CMNFI 1970-0581, 6, 41.3-65.5 mm standard length, Gilan, Caspian Sea near Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1970-0587, 3, 69.0-91.4 mm standard length, Mazandaran, Babol River at Babol Sar (36º43'N, 52º39'E); CMNFI 1970-0589, 4, not kept, Gilan, Sefid River opposite Kisom (37º12'N, 49º54'E); CMNFI 1979-0431, 2, 240.9-265.5 mm standard length, Mazandaran, bazaar at Now Shahr (no other locality data); CMNFI 1979-0437, 1, 242.0 mm standard length, Gilan, Sefid River 2 km west of Astaneh (37º16'30"N, 49º56'E); CMNFI 1979-0452, 2, 53.5-56.5 mm standard length, East Azarbayjan, Qezel Owzan River 6 km from Mianeh (37º23'N, 47º45'E); CMNFI 1979-0486, 2, 69.2-78.8 mm standard length, Golestan, stream in Atrak River drainage (37º44'N, 56º18'E); CMNFI 1979-0488, 1, 95.8 mm standard length, Golestan, Atrak River at

Maraveh Tappeh (37º55'N, 55º57'30"E); CMNFI 1979-0491, 1, 191.5 mm standard length, Golestan, Gorgan River 15 km northeast of Kalaleh (ca. 37º33'N, ca. 55º44'E); CMNFI 1979-0685, 1, not kept, Gilan, Sefid River (ca. 37º22'N, ca. 49º57'E); CMNFI 1979-0686, 19, 30.2-77.4 mm standard length, Gilan, Sefid River above ferry (37º24'N, 49º58'E); CMNFI 1979-0689, 2, not kept, Gilan, Sefid River at Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1979-0695, 4, 51.4-189.6 mm standard length, Gilan, Sefid River at Manjil Bridge (36º46'N, 49º24'E); CMNFI 1979-0696, 4, not kept, Gilan, Sefid River estuary (ca. 37º28'N, ca. 49º54'E); CMNFI 1979-0788, 2, 152.0-202.4 mm standard length, Golestan, Gorgan River at Khadje Nafas (37º00'N, 54º07'E); CMNFI 1979-0790, 1, 207.5 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0116, 8, 36.3-62.4 mm standard length, Gilan, Sefid River at Astaneh Bridge (37º16'30"N, 49º56'E); CMNFI 1980-0123, 8, 27.8-42.7 mm standard length, Gilan, Sefid River around Dakha (ca. 37º22'N, ca. 49º57'E); CMNFI 1980-0127, 1, 274.5 mm standard length, Gilan, Caspian Sea near Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1980-0131, 17, 24.3-61.8, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0132, 8, 29.6-43.0 mm standard length, Gilan, Sefid River at Kisom (37º12'N, 49º54'E); CMNFI 1980-0135, 1, 39.3 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0138, 2, 132.5-137.6 mm standard length, Gilan, Sefid River estuary (ca. 37º28'N, ca. 49º54'E); CMNFI 1980-0490, 122.1check mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0494, 3, 266.7-301.7 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0905, 1, 188.9 mm standard length, Golestan, Gorgan River at Khadje Nafas (37º00'N, 54º07'E); CMNFI 1980-0908, 3, 67.2-91.3 mm standard length, Gilan, Sefid River estuary (ca. 37º28'N, ca. 49º54'E); CMNFI 1980-0925, 12, 38.5-61.9 mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 2008-0131, 2, 245.7-272.8 mm standard length, Markazi, Shah River (no other locality data).

## ***Luciobarbus caspius***
(Berg, 1914)



*Luciobarbus caspius*, 79.5 cm total length, ZISP 17042, Azerbaijan, lower Kura River, after Berg (1948-1949).

*Luciobarbus caspius*, Gilan, Anzali Shore, November 1997, Keyvan Abbasi.

**Common names.** Zardehpar or zardek (in reference to yellow fins), orenj (in reference to orange fins), sas or sos mahi, sas mahi-e sar kochak (= small head fish), sas mahi khazari and sassmahi-ye Daryaye-Khazar (= Caspian Sea fish, sos and sas being unknown but referring to "*Barbus*").

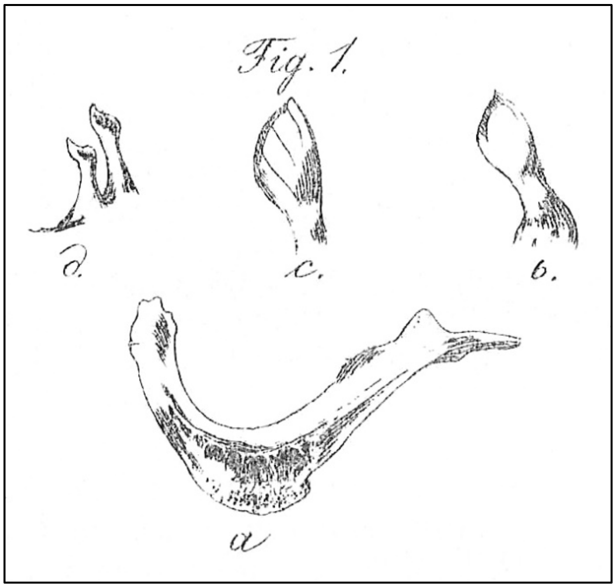
[Xazar sirbiti or shirbit in Azerbaijan; Kaspiiskii usach or Caspian barbel and korotkogolovyi ustach or short-headed barbel in Russian; Caspian barbel, short-headed barbel].

**Systematics.** The Iranian subspecies was *Luciobarbus brachycephalus caspius* (Berg, 1914), described originally from the Caspian Sea basin (Eschmeyer *et al*., 1996). Karaman (1971), however, considered differences with the type subspecies of the Aral Sea basin to be minor and not worthy of subspecific recognition. Differences are in body proportions and the Caspian barbel has a smaller eye, lower dorsal fin, less deep body and head, longer pectoral-pelvic distance, shorter pelvic-anal distance, and dorsal fin further back than in the Aral barbel (Berg, 1948-1949). Fricke *et al*. (2007) listed this taxon as a full species but also have *brachycephalus* in the same system in Turkey (Kura-Aras). *Barbus brachycephalus* Kessler, 1872 was originally described from the Syr Darya in Uzbekistan. The subspecies *caspius* is now recognised as a species in the *Catalog of Fishes* (downloaded 15 November 2015).

Howes (1987) considered the generic placement of this species (as *brachycephalus*) to be problematical. It has slender barbels, 7 dorsal fin branched rays and the cranium is broad and flat, all characters at odds with his *Barbus sensu stricto*. Doadrio (1990) placed it in the subgenus *Luciobarbus* Heckel, 1843 based on a series of four synapomorphic osteological characters, namely the exoccipital contacts the pterotic "largely" (*sic*, probably broadly), high medial process of the urohyal, narrow exoccipital apophysis of the pterotic, and wide 4th and 5th infraorbitals.

Laloei *et al*. (2016) using microsatellite DNA on fish identified as *L. brachycephalus caspius* found the genetic divergence was significantly different between samples of Gilan and Tajan, Mazandaran and Sefid River.

*Barbus obtusirostris* (*non* Valenciennes, 1842) Yakovlev, 1870 (*nomen praeoccupatum*), described from the Volga River delta, Russia, is a synonym.




*Barbus obtusirostris*, pharyngeal arch and teeth, after Yakovlev (1870) which does not illustrate a whole fish.

Syntypes of *Barbus brachycephalus caspius* are in the Zoological Institute, Russian Academy of Sciences, St. Petersburg under ZISP 2982 (8 fish), Transcaucasia, ZISP 3895 (8), Lenkoran, ZISP 9076 (22), 9085 (10), 9109(2), 9117(11), 9118(1), 9124(8), 9128(9), all from the lower Aras River and Lenkoran, and ZISP 17042(2), 17043(1), 17044(1), all from the Bank Fishery along the lower Kura River. Syntypes under ZISP 10619 are apparently lost and a fish under ZISP 9108 is actually a *Luciobarbus capito* (Bănărescu and Bogutskaya, 2003). A possible syntype of *B. brachycephalus* from the Aral Sea is in the Naturhistorisches Museum Wien (NMW 53971) (Almaça, 1986). The NMW card index listed this fish plus two fish in NMW 53972 and one fish in NMW 53973 as syntypes. Syntypes in St. Petersburg, Russia are lost (Bogutskaya in Bănărescu and Bogutskaya, 2003).

**Key characters.** The 7 dorsal fin branched rays and the predorsal distance shorter than the postdorsal distance distinguishes this species from *Luciobarbus capito* and *L. mursa,* the other Caspian Sea relatives.

**Morphology.** The body is elongate and rounded with a short head. The back rises sharply behind the head to level off on the back before the dorsal fin. The whole back after the initial rise from the head is straight. The body is deepest at the dorsal fin origin. The snout is narrow and tapering with a groove in front of the nostrils in some fish. It projects beyond the upper lip but does not obscure it. The caudal peduncle is compressed and deep. The eye is well into the anterior half of the head. The mouth is moderate in size and subterminal. Lips are thin to moderate, without a median lobe on the lower lip, and barbels are papillose and of moderate thickness, tapering evenly. The anterior barbels can reach the level of the posterior eye margin or beyond and the posterior barbels reach or pass the preopercle level but barbel lengths show marked individual variation. The dorsal fin height in young is greater than head length but less in older fish. The dorsal fin margin is emarginate and the dorsal fin origin is anterior to the level of the pelvic fin origin. Since the dorsal fin is far anterior on the body, its tip is remote from the anal fin origin level. The dorsal fin spine is strong and small denticles extend almost to its tip. The caudal fin is deeply forked with a rounded ventral tip and a more pointed dorsal tip. The anal fin margin is rounded to slightly emarginate, and the fin does not extend back to

the caudal fin base. The pelvic fin is rounded and very remote from the anus. The pectoral fin is rounded and does not extend back to the pelvic fin origin.

Ramin and Dostdar (2015) provided morphometric and meristic data on this species.

Dorsal fin with 3-5, usually 4, unbranched and 6-8, usually 7, branched rays, anal fin with 2-3, usually 3, unbranched and 5-6, usually 5, branched rays, pectoral fin branched rays 14-17, and pelvic fin branched rays 7-8, usually 8. The dorsal fin denticles on the last unbranched ray are usually moderate in number, but may be lost in very large adults, are usually well-developed and extend along four-fifths of the ray (Karaman, 1971). This ray is very strong. Lateral line scales 62-90, commonly 65-77. There is a pelvic axillary scale. Scales are elongate with a central focus and few anterior and posterior radii in young fish. Total gill rakers number 16-27, short and reaching the one below when appressed. Pharyngeal teeth are 2,3,5-5,3,2, hooked at the tip with the fourth tooth of the inner row large and blunt and the first three spatulate, rarely 2,3,4-5,3,2, 2,3,4-4,3,2 or 2,2,4-4,2,2. The gut is coiled anteriorly. Total vertebrae number 45-50, usually 46-49, mode 48. The chromosome number is 2n = 100 (Klinkhardt *et al*., 1995).

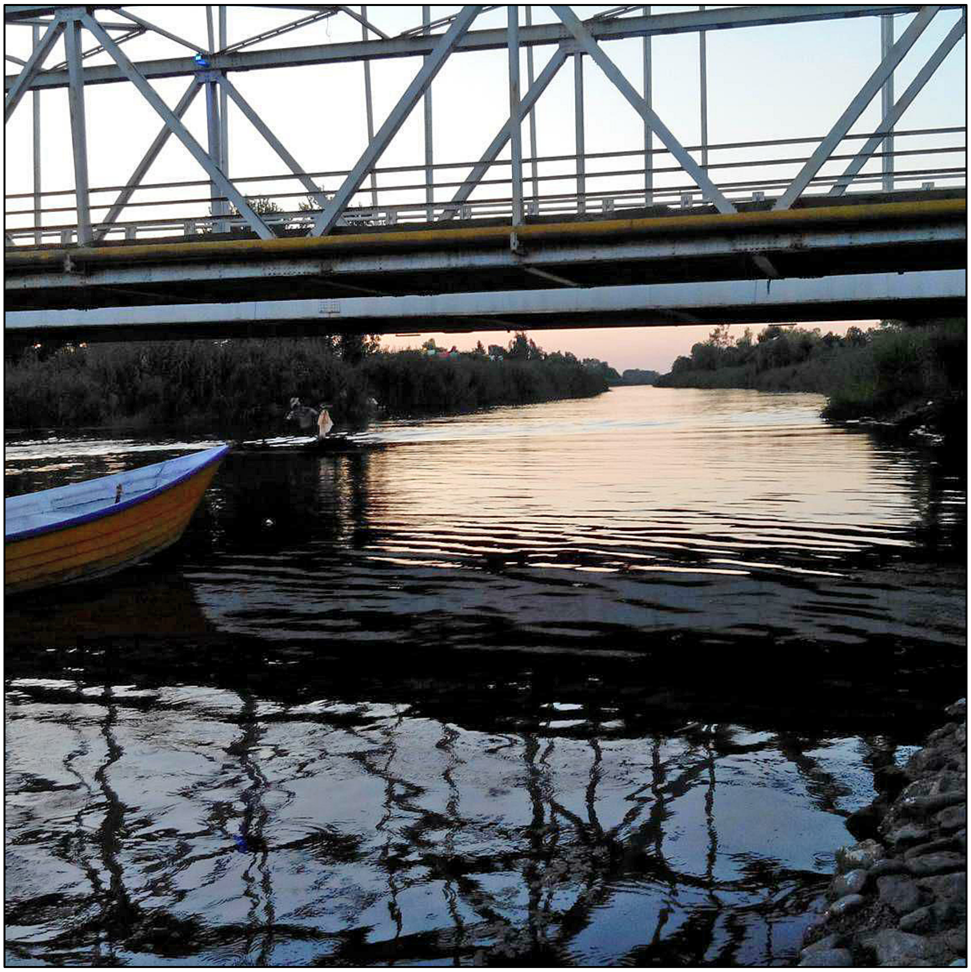
Meristic values for Iranian specimens are:- dorsal fin branched rays 7(3), anal fin branched rays 5(3), pectoral fin branched rays 16(1) or 17(2), pelvic fin branched rays 8(3), lateral line scales 69(2) or 71(1), total gill rakers 18(1) or 19(2), and pharyngeal teeth 2,3,5-5,3,2(2) or 2,3,4-5,3,2(1).

**Sexual dimorphism.** Abdurakhmanov (1962) reported on fish from the Kura River basin where males have a longer dorsal fin base and larger eye and females have a greater maximum body depth, width and girth. Bogutskaya in Bănărescu and Bogutskaya (2003) reported that males have a shorter head and longer unpaired fins, while nuptial tubercles and colouration are absent.

**Colour.** The back is dark green, flanks and belly lighter, and the two areas may contrast as in *Luciobarbus capito*. There are no dark spots on the body. The fins are greyish with the ventral fins lightest and the dorsal and caudal fins dark on rays and membranes. All fins may have yellow to red tinges, with the lower fins being the most red. The anal fin may have a central red area and the anterior dorsal fin rays may be red, becoming yellowish distally and posteriorly. The peritoneum is brown.

**Size.** Reaches 1.2 m and 14.5 kg (Berg, 1948-1949).

**Distribution.** This species is found in the Caspian Sea and its tributaries. In Iran, it was formerly known from the Anzali Talab but is probably no longer present (Holčík and Oláh, 1992; but see below) and it was listed as rare in the Sefid River (Derzhavin, 1934). Nedoshivin and Iljin (1929) and Nevraev (1929) recorded it from the Astrabad, Enzeli (= Anzali) and Gorgan regions. Recent works place it in rivers from the Astara to the Neka and Gorgan Bay peninsula, in the Anzali Talab, and along the whole Caspian Sea coast but these are summaries of past and present distributions (Riazi, 1996; Karimpour, 1998; Abbasi *et al*., 1999; Kiabi *et al*., 1999; Abdoli, 2000; Abdoli and Naderi, 2009). This species is now very rare in the Caspian Sea basin of Iran, with only a couple of specimens found in a survey (M. Ramin, pers. comm., 2000). River records include the Babol, Gorgan, Kargan, Langarud, Polrud (= Pol-e Rud), Shah, Sheikan and Sowsar.



Gilan, Langarud
(Langerud river, CC BY-SA 4.0, lightened, Ehsanbadrikouhi).

The related *L. brachycephalus* (Kessler, 1872) is recorded from the Karakum Canal and Kopetdag Reservoir in Turkmenistan (Shakirova and Sukhanova, 1994; Sal'nikov, 1995) and may eventually reach Iranian waters in the Tedzhen (= Hari) River basin.

**Zoogeography.** Almaça (1984b) considered this species (as *L. brachycephalus*) to be a Sarmatian Sea remnant, a Neogene brackish-water basin. See also under the genus.

**Habitat.** This species is found in rivers, streams, lagoons, marshes and brackish environments. It has been recorded at depths of 11.0-11.9 m in the Iranian Caspian Sea (Knipovich, 1921). Riazi (1996) reported that this species migrated into the Siahkeshim Protected Region of the Anzali Talab. Naderi Jolodar and Abdoli (2004) stated that it was more abundant in Gilan than in Mazandaran coastal waters.

It entered rivers to spawn but did not ascend as high as *Luciobarbus capito*. It preferred deep sections of rivers with stony and gravel bottoms. In the Caspian Sea it may be found at 13-25 m depth. On the Kura River in Azerbaijan there is a spring run and one in August-September. The spring run begins in March and lasts about 50 days; the summer run starts after a short interruption and lasts about 190 days. The water temperature at the start of the spring run is 6.7-11.0°C but the most intensive migration is in summer at 25.2-27.2°C (Bogutskaya in Bănărescu and Bogutskaya, 2003). Spring run fish spawned in the same year. Young females usually entered the sea immediately but males may remain in fresh water for 3-5 years.

Spawners returned to the sea.

**Age and growth.** Most fish examined by Razivi *et al*. (1972) from commercial catches in Iran were 2-7 years old, 38.0-69.0 cm long and weighed 698-4,658 g. Low recruitment was attributed to poor spawning success, a result of water abstraction during its spawning season. Sexual maturity was attained at 6-8 years. Holčík and Oláh (1992) noted that the Anzali region catches were dominated by three- to five-year-old fish, 38-71 cm fork length, with rapid growth, and a weight of 2.0 kg attained during the fifth year of life. Amouei *et al*. (2013) found a maximum age of $5^+$ years and total length of 48.3 cm in fish caught by artisanal fishermen. Mean length was 27.53 cm, male:female sex ratio was 1:1.1 with no significant difference, and length-weight relationship was $W = 0.011TL^{2.939}$. Mouludi-Saleh *et al*. (2021) examined 41 fish, 30.2-56.5 cm total length, from the Gilan coast and recorded a *b* value of 3.17, positive allometric, and a condition factor of 0.79.

Abdurakhmanov (1962) gave a maximum life span of 13 years in Azerbaijan. Females lived longer than males that only reached 10 years (Bogutskaya in Bănărescu and Bogutskaya, 2003).

**Food.** No detailed literature reports but gut contents of small specimens from Iran contained crustaceans, and insects such as, curiously, ants, thrips and mosquitos. This fish evidently feeds on insects taken at the surface and is reported as leaping out of the water to take flying insects (Bogutskaya in Bănărescu and Bogutskaya, 2003). Mayflies and caddisflies were also taken and gut contents included detritus. Crustaceans were the main food taken in the Caspian Sea (Abdurakhmanov, 1962) but molluscs were also recorded, as well as small fish.

**Reproduction.** This barbel spawned in swift streams over pebbles or sand during July and August in Iran and the eggs attached to rocks (Razivi *et al*., 1972). Holčík and Oláh (1992) stated that eggs were semipelagic, hatching as they drifted downstream over two days at 25°C. Fry were carried downstream. Up to 1,259,000 bright-yellow eggs were produced of 1.4 mm diameter and the spawning season on the Kura River began at the end of April, peaked in June and ended at the end of August. Favoured temperatures were 20-23°C (Abdurakhmanov, 1962). Berg (1948-1949) noted two runs, in spring and August-September, the former having mature gonads and spawning during the same year. First spawning was at 5-7 years of age with females taking a year longer to mature than males (Bogutskaya in Bănărescu and Bogutskaya, 2003).

**Parasites and predators.** Molnár and Jalali (1992) recorded the monogenean *Dactylogyrus affinis* from this species in the Sefid River. Sattari *et al*. (2008) reported the nematodes *Eustrongyloides excisus* and *Anisakis* sp. from fish along the southern Caspian Sea shore. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Lamproglena pulchella* on this species. Daghigh Roohi (2016) recorded *Dactylogyrus anchoratus* from fish in the Anzali Wetland.

**Economic importance.** This species was caught as a food fish in Iran. Nevraev (1929) recorded catches of 37 to 962 individuals from the Anzali region for the years 1914-1915 to 1917-1918. It was abundant in the Anzali Talab with total catches for Iran of 54.6 t and 32.9 t in 1969/70 and 1970/71 (28.7 t and 14.4 t for the Anzali region alone) but few fish were captured by the time of the report by Holčík and Oláh (1992) (note that these figures were taken from Appendix 11, on page 10 they are reversed). They were caught in rogas (outflowing rivers from the Anzali Talab) and inflowing rivers of the talab in late winter and early spring. On the Kura River of Azerbaijan average weight in catches was 5.6 kg for females and 3.5 kg for males and the catch from 1920-1944 varied from 0.2 to 3.6 thousand centners.

Robins *et al*. (1991) listed this species (as *L. brachycephalus*) as important to North Americans. Importance was based on its use as food and in aquaria.

**Experimental studies.** None.

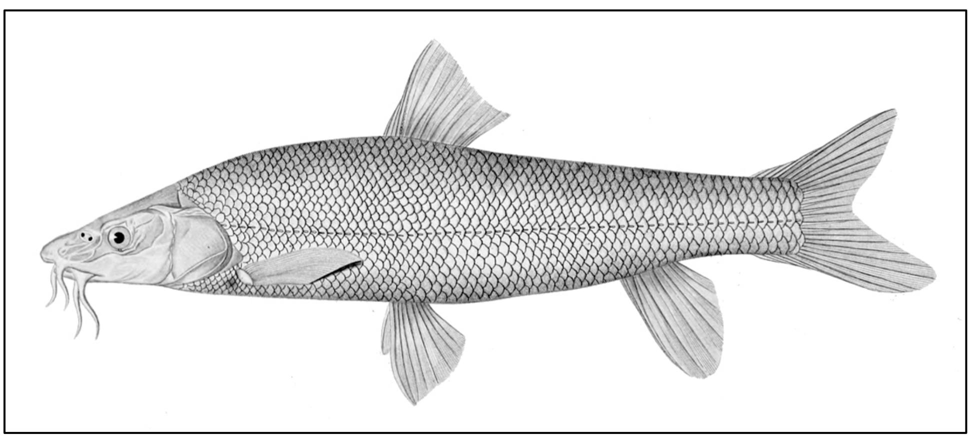
**Conservation.** It is assessed as Vulnerable in Turkey (Fricke *et al*., 2007) and Vulnerable by the IUCN (2015) (as *L. brachycephalus*) and Smith *et al*. (2014) and fishing is banned in the Caspian Sea. Stocks of this species have declined because of poor habitat for spawning and the construction of dams and weirs that restricted access to spawning grounds. Poaching is also a factor in the Caspian Sea. Water abstraction for irrigation during the summer spawning season would have to be balanced against the requirements of the fish. Larvae of spring spawners were lost when they entered irrigation channels and become stranded in fields (Razivi *et al*., 1972). This species is not cultured so stocks are not replenished.

Once known from the Anzali Talab, it is now absent to rare there and apparently replaced by *Luciobarbus capito* (Holčík and Oláh, 1992). Kiabi *et al*. (1999) considered this species to be critically endangered in the south Caspian Sea basin according to IUCN criteria. Criteria included commercial fishing, sport fishing, few in numbers, habitat destruction, limited range (less than 25% of water bodies), absent in other water bodies in Iran, and absent outside the Caspian Sea basin.

This species is regarded as critically endangered through illegal overfishing, pollutants, and the destruction of breeding and nursery grounds. Only two specimens were caught in the three years prior to 2000 during a study of “*Barbus*” species in Iran. Additionally, during the six-month beach seine fishing season (October to April) for the years 1998 and 1999 along the Caspian shore, no specimens were caught in 138 beach seines used 51,000 times (M. Ramin, pers. comm., 2000). Naderi Jolodar *et al*. (2017) reported it to be in serious danger of extinction in Iran.

**Sources.** Iranian material:- CMNFI 1970-0553, 2, 109.5-117.8 mm standard length, Gilan, Sowsar Roga River (37º27'N, 49º30'E); CMNFI 1980-0120, 1, 115.3 mm standard length, Mazandaran, Babol River at Babol Sar (36º43'N, 52º39'E); CMNFI 1980-0905, 3, not kept, Golestan, Gorgan River at Khadje Nafas (37º00'N, 54º07'E).

## ***Luciobarbus conocephalus***
(Kessler, 1872)



*Luciobarbus conocephalus*, after Kessler (1874).

*Luciobarbus conocephalus*, Razavi Khorasan, Hari River basin, Soheil Eagderi.

**Common names.** Zardehpar Harirud (from yellow fins and Hari River), orenj Hari Rud (= in reference to orange fins).

[Shir mahi (= milk fish) in Afghanistan (Saberi, 1998), possibly zaghara mahi (Ahmadzai, 2017); Turkestanskii usach or Turkestan barbel, zheltyi usach (= yellow barbel), zolotoi usach (= golden barbel), sazan usach (= carp barbel) in Russian, sugön or kayaz by Kazakhs on the Syr Darya, kayaz by Kazakhs and Karakalpaks in the delta of the Amu Darya, ten'ge-balyk by Kazakhs on the Chu River; Hari barbel].

**Systematics.** The type locality of this species is the Zeravshan River, Uzbekistan and syntypes are under ZMMU (Zoological Museum of Lomonosov Moscow State University) P-1513 (2) and P-1518 (1). See below under **Distribution** for reference to evidence of validity of this species.

**Key characters.** Distribution is key, this species being found in the Hari River basin. Lips are thin, there are modally 8 dorsal fin branched rays and 56-70 lateral line scales.

**Morphology**. The back is convex in front of the dorsal fin. The head profile is rectilinear or slightly convex. The head is relatively long. The snout is narrowly rounded and short. The lips are thin and there is no median lobe to the lower lip. Barbels are slender, the anterior one reaching back past the anterior eye margin and the posterior one reaching the middle or rear edge of the eye. The dorsal fin is slightly to obviously emarginate and its origin is slightly in advance of the level of the pelvic fin origin. The dorsal fin spine is moderate with weak to moderate denticles extending along three-quarters of the spine. The depressed dorsal fin does not reach back to the anal fin origin level. The caudal fin is moderately forked with rounded tips, particularly the lower lobe. The anal fin margin is rounded and the fin may, or may not, reach back to the caudal fin base. The pelvic fin margin is rounded and the pectoral fin margin is straight. The anal fin does not reach back to the anal fin origin and the pectoral fin does not reach the pelvic fin origin.

Dorsal fin unbranched rays 3-5, branched rays 7-9, usually 8, anal fin unbranched rays 2-3, branched rays 3-7, usually 5, pectoral fin branched rays 17-18, pelvic fin branched rays 8, lateral line scales 56-70, mostly 63-65, gill rakers 8-22 (presumably some are lower arch only counts), and total vertebrae 48-50. Pharyngeal teeth are 2,3,5, hooked, the fourth and fifth in the outer row being the largest and smallest respectively (Almaça, 1986).

**Sexual dimorphism.** Usmanova (1971) found 13 of 26 morphological characters differed between the sexes with females clearly distinguished by fin size (dorsal lower, pectoral longer (later stated to be shorter), anal higher and longer). Females also have a longer postorbital, smaller eye, less deep body in its shallowest part (presumably the caudal peduncle), broader forehead (interorbital) and a longer snout. Males have large tubercles on the

snout and along the upper sides of the lip during spawning.

**Colour.** Usually uniformly coloured with a golden-yellow tinge but some may have a distinct boundary between a dark golden-green dorsal and a light yellowish ventral body. The belly is light and yellow tinged. The head is greenish on the sides above the eyes. Dorsal and caudal fins are bluish-grey, pectoral fins grey and other fins a light reddish. Lower fins may be an obvious yellow to orange basally. The caudal fin may be spotted. Barbels are basally yellow and dark apically. Young fish are darkly spotted as are some adults.

**Size.** Attains 76.8 cm total length (Berg, 1948-1949) and 5.0 kg.

**Distribution.** This species was found rarely in the Aral Sea, and abundantly in the Amu Darya (and its upper reaches), Syr Darya, Zeravshan and Chu rivers of Central Asia. Formerly treated as a subspecies of *L. capito*, it was reported from the Karakum Canal, Kopetdag Reservoir and Uzboi lakes in Turkmenistan (Shakirova and Sukhanova, 1994; Sal'nikov, 1995) and it was thought it would eventually reach the Hari River and Caspian Sea basins in Iran (www.briancoad.com, downloaded 16 October 2019). Mousavi-Sabet *et al*. (2018) reported *L. cf. capito* from the Hari River basin in Iran in the Dousti Dam, later confirmed as *L. conocephalus* by Eagderi *et al*. (2021). Jouladeh-Roudbar *et al*. (2020) recorded *L. conocephalus* from the Hari River basin but listed it as native. They cited unpublished molecular and morphological data that showed this taxon to be a full species. Eagderi *et al*. (2021) documented this occurrence of the species near Pol-e Khatun on the Hari River of Iran using morphology and DNA.

The material listed below under CMNFI 2008-0138 from the Hari River in Iran may be *L. conocephalus* but the material is small and the only character distinguishing it from *L. capito* (dorsal height) in Berg (1948-1949) is given as 15-16% body length in fish 40 cm standard length (10-14% in large *L. conocephalus* more than 50 cm standard length). The values for *L. capito* in fish 40 cm standard length are 13-14%. The dorsal heights in standard length for the two Iranian fish are 21.3-22.1%, presumably size-related values and not distinctive in these juveniles about a fifth of the size of the fish examined by Berg (1948-1949).

**Zoogeography.** See under the genus.

**Habitat.** Some populations inhabit rivers or streams permanently while others migrate into still waters to overwinter after spawning in groups. Gravel bottoms and fast water are preferred and it stays in deep water during the day, approaching marginal shallows and on shallow banks at night for feeding (Usmanova, 1971).

**Age and growth.** Fish of ages 1+ to 7+ years were found in catches in the Zeravshan River basin of Uzbekistan. In commercial catches, individuals were found ranging in age from 2+ to 6+ years (Kamilov, 1966).

**Food.** In the Kattakurgan Reservoir of Uzbekistan during summer, this barbel ate chiefly the larvae and pupae of tendipedids, remains of higher plants and detritus. In autumn, larval Diptera, pupae of terrestrial and aquatic insects as well as beetles, ants and plant remnants were found in stomachs. The stomachs of barbel from the Kuyumazar Reservoir contained tendipedid larvae, mayflies, Characeae and detritus. The summer food of the Tudakul barbel consisted mainly of Characeae and detritus (Kamilov, 1966).

**Reproduction.** This fish bred in May-June in the Zeravshan River. Sexual maturity began at a length of 20-25 cm and 2-4 years of age. The fecundity of fish aged 4+ to 7+ ranged from 41,166 to 74,000 eggs (Kamilov, 1966)

**Parasites and predators.** None reported from Iran.

**Economic importance.** Populations of this fish in Central Asia have formed a

commercial fishery and are sought by anglers (Berg, 1948-1949; Usmanova, 1971). This species may be the one represented in the Oxus Treasure by a hollow gold fish dating from the 5th-4th century B.C. in the Achaemenid period, excavated at Takht-i Kuwad, Tajikistan (S. Eagderi in Burton, 2016). Appropriately, this species is found in the Zeravshan River which means "spreader of gold" in Farsi.

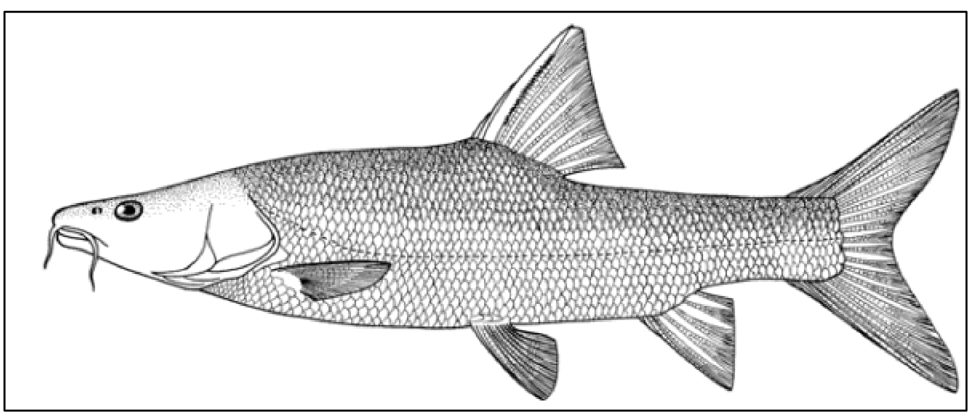
Gold fish from the Oxus Treasure, British Museum
(CC BY-NC-SA 4.0 ).

**Experimental studies.** None in Iran.

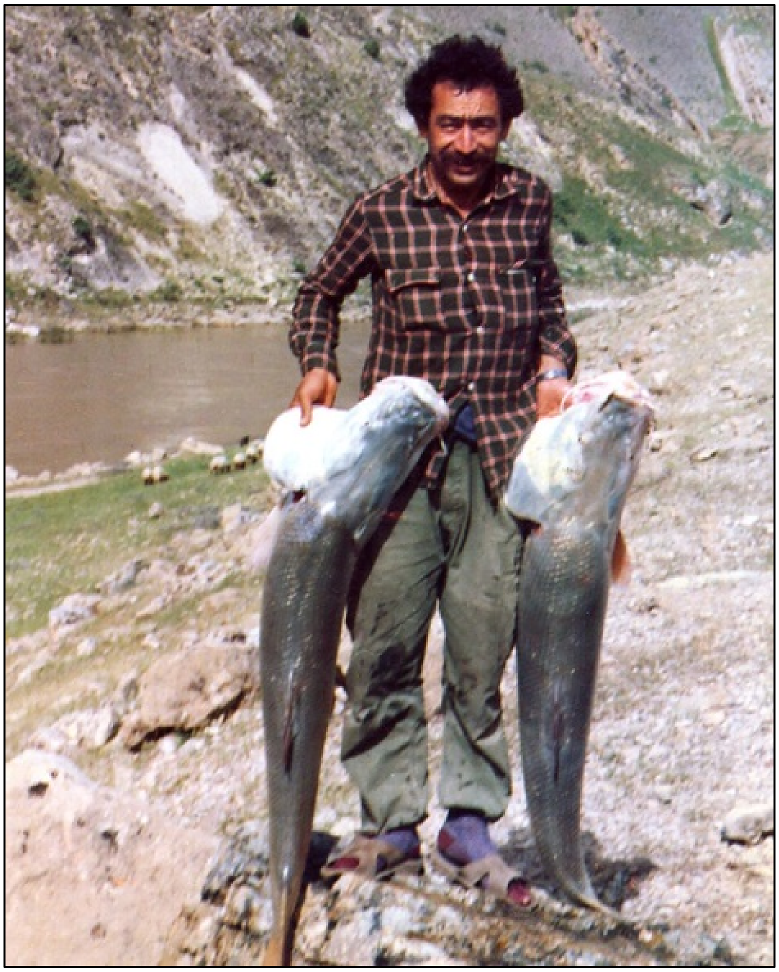
**Conservation.** Jouladeh-Roudbar *et al*. (2020) listed it as Data Deficient.

**Sources.** Iranian material: *Luciobarbus cf. conocephalus*, CMNFI 2008-0138, 2, 75.8-85.5 mm standard length, Razavi Khorasan, Hari River at Sarakhs (36º32'N, 61º11'E).

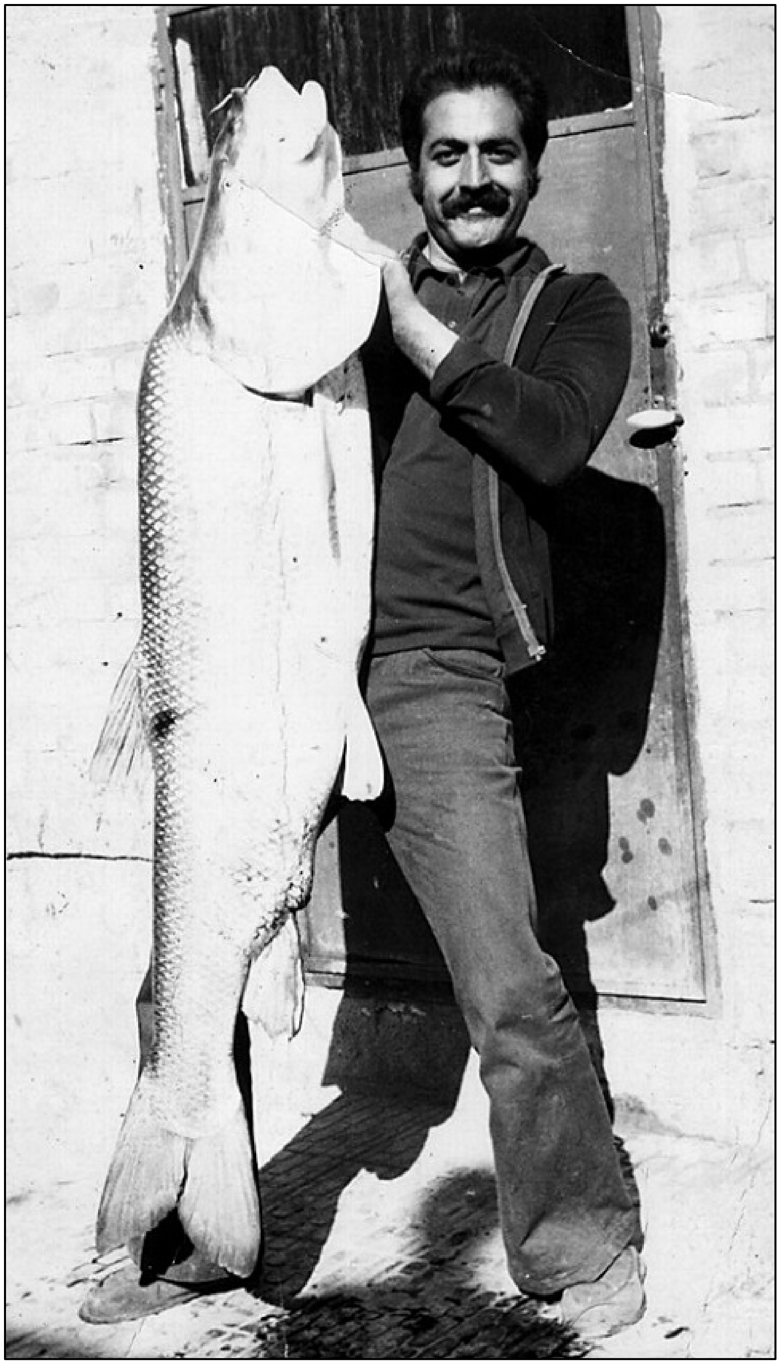
***Luciobarbus esocinus***
Heckel, 1843



*Luciobarbus esocinus*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Luciobarbus esocinus*, Ilam, Darreshahr, Simareh River,
April 1987, N. Atarody and Bahram H. Kiabi.



*Luciobarbus esocinus*, Kermanshah, Simareh River, Bahram H. Kiabi.

*Luciobarbus esocinus*, Ilam, Simareh River,
29 June 2010, H. Abbasi and Bahram H. Kiabi.

*Luciobarbus esocinus*, Khuzestan, Brian W. Coad.

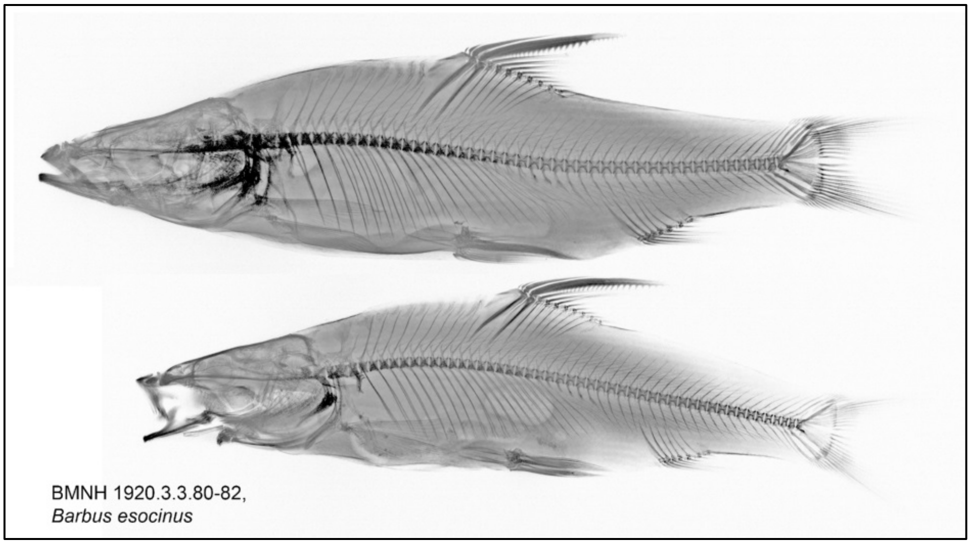
*Luciobarbus esocinus*, Khuzestan, Dez River, 1.5 m caught by S. O. Mousaor, Brian W Coad.

*Luciobarbus esocinus*, Khuzestan, Dez River, 1.5 m caught by S. O. Mousaor, Brian W Coad.

*Luciobarbus esocinus*, 1.32 m, 32-34 kg, Iraq, Baghdad, Camp Slayer (after Coad, 2010).

*Luciobarbus esocinus*, Khuzestan, Dez River,
pharyngeal teeth, 1.5 m caught by S. O. Mousaor,
Brian W Coad.

*Luciobarbus esocinus*, pharyngeal teeth 146.0 mm,
Khuzestan, Dez River, 1.5 m long,
caught by S. O. Mousaor, Brian W Coad.




*Luciobarbus esocinus*, BM(NH) 1920.3.3:80-82, Iraq, Basrah,
Natural History Museum Data Portal (data.nhm.ac.uk), https://doi.org/10.5519/0002965.

**Common names**. Bach or soong in northern Khuzestan and Lorestan; anzah, anzeh, narbach, and anzeh-bach at Ahvaz and in southern Khuzestan; balzard; simreh kapoor at Khorramabad from Mortazavi *et al*. (2016) (all meanings unknown).

[Bizz (in Iraq), farkh-el-biz, farch (farikh-al-bizz = cheerful one (Heckel, 1843b) or young of bizz (Mikaili and Shayegh, 2011)), mangar or manjar (perhaps from Semitic n-g-r for flow or small pond, hence a migratory or running fish or pond dweller (Mikaili and Shayegh, 2011)), all in Arabic; cero and mangar (local names in eastern Turkey) (Kaya *et al*., 2016; Çiçek *et al*., 2020); "Euphrates salmon" or "Tigris salmon" (although not a salmon of course), pike barb, pike barbel, wolf-barb].

**Systematics.** Howes (1987) placed this species in his *Barbus sensu stricto*. *Labeobarbus Euphrati* Sauvage, 1882 described from "Biredjik (Euphrates)", Turkey (not "Irak" as in Bertin and Estève (1948)) is a synonym.

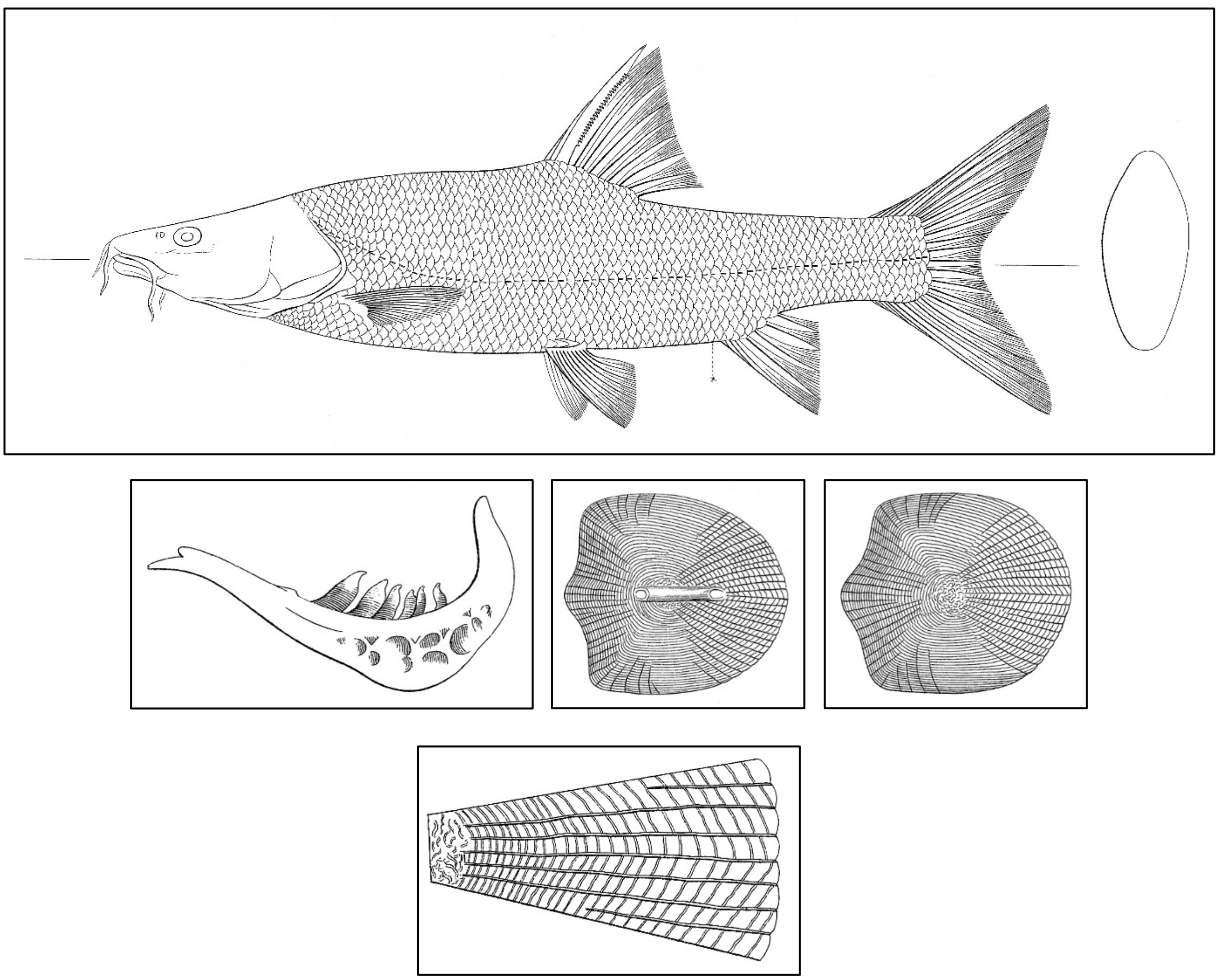
Karaman (1971) placed this species in the synonymy of "*Barbus*" *xanthopterus* as he considered the only difference to be scale count and the range of variation for these species is unknown. Almaça (1983, 1986) agreed that several meristic characters are similar while the main differences are a shorter head and barbels in *esocinus* and dotted colouration in *esocinus* as opposed to uniform in *xanthopterus*. He maintained them as separate species because information on variability in characters was lacking.

Abasi Dehkord *et al*. (2018) used the COI gene to study this species and *L. xanthopterus*, concluding these species are closely related, indicating a recent divergence or hybrid origin, and they have a Palaearctic origin.

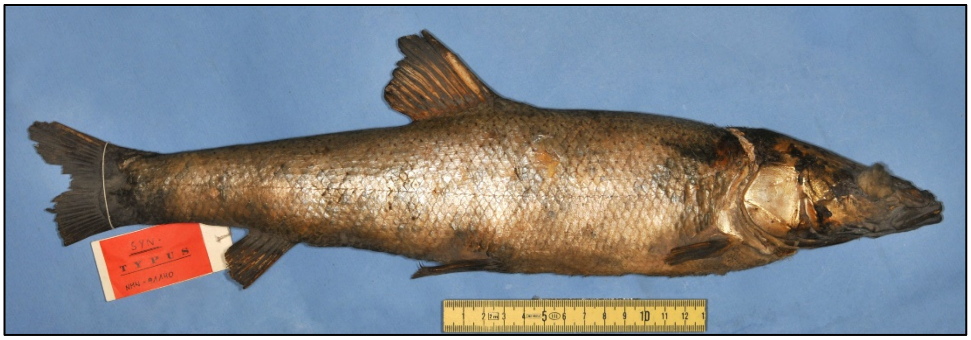
Examination of the types of *L. esocinus* (NMW 54088, 2, 58.5-61.5 mm standard length, NMW 54091, 372.4 mm, NMW 54092, 321.3 mm) and *L. xanthopterus* (NMW 54841a (a syntype), 216.5 mm, NMW 54786 (not a type), 292.8 mm) in Vienna showed the following differences. Head size differs in the two taxa in that *esocinus* postorbital length is very elongate and the head tapers anteriorly in a distinctive fashion. Head length in standard length is 3.2-3.6, mean 3.4, for *esocinus* and 4.0-4.2, mean 4.1, for *xanthopterus*. Postorbital length in standard length is 5.9-7.2, mean 6.5, for *esocinus* and 7.7-7.8, mean 7.8, for *xanthopterus*. Total gill raker counts are 8-10, mean 9.3 for *esocinus* and 12-13, mean 12.5 for *xanthopterus*. Larger

*esocinus* appear to lose anterior rakers with age but still have fewer than *xanthopterus* of similar size. Lateral line scale counts are 63-70, mean 67.3 in *esocinus* and 57-60, mean 58.5 in *xanthopterus*. On this limited basis, I maintained the two species as distinct.

Almaça (1986) recorded syntypes of *Luciobarbus esocinus* in the Naturhistorisches Museum Wien from the type locality as given by (Heckel, 1843b) “bei Mossul in Tigris”, Iraq (NMW 54088 (2 specimens), NMW 54091 (1), and NMW 54092 (1) but Heckel (1843b) did not specify the number of types). A syntype is in the Senckenberg Museum Frankfurt (SMF 454, formerly NMW, 281.2 mm standard length) and another syntype is also there but dried (SMF 6785, formerly NMW) (F. Krupp, pers. comm., 1985). The catalogue in Vienna listed two fish in spirits and two fish stuffed. Dried syntypes photographed by Naturhistorisches Museum Wien staff have the numbers shown below and were not listed in the *Catalog of Fishes*, downloaded 23 July 2020.



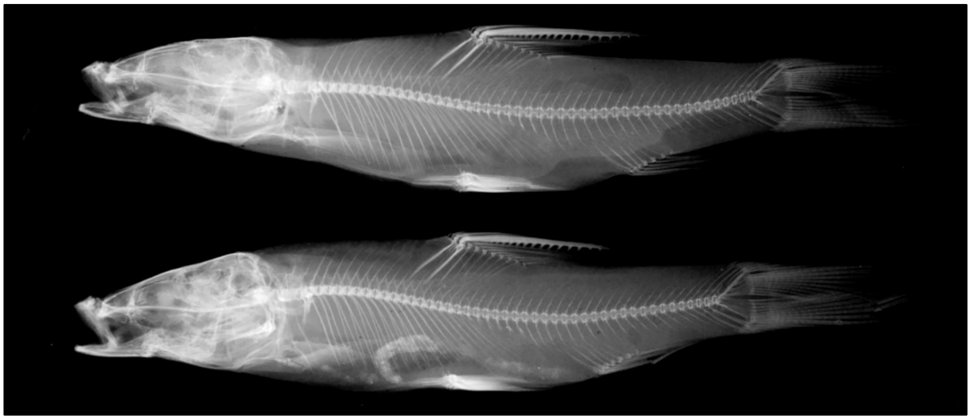
*Luciobarbus esocinus*,
body and cross-section, pharyngeal arch, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.



*Luciobarbus esocinus*, syntype, NMW 91140, Naturhistorisches Museum, Wien.

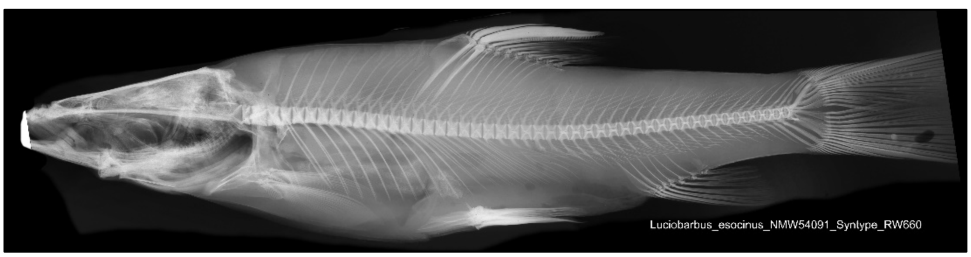
*Luciobarbus esocinus*, syntype, NMW 92996, Naturhistorisches Museum, Wien.


*Luciobarbus esocinus*, syntypes, NMW 54088, Naturhistorisches Museum, Wien.



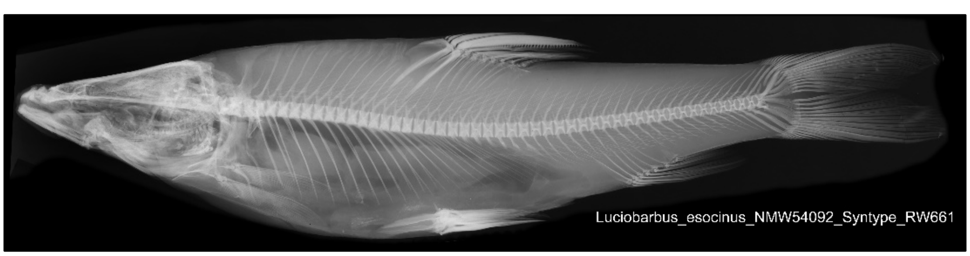
*Luciobarbus esocinus*, syntypes, NMW 54088, Naturhistorisches Museum, Wien.

*Luciobarbus esocinus*, syntype, NMW 54091, Naturhistorisches Museum, Wien.




*Luciobarbus esocinus*, syntype, NMW 54091, Naturhistorisches Museum, Wien.

*Luciobarbus esocinus*, syntype, NMW 54092, Naturhistorisches Museum, Wien.




*Luciobarbus esocinus*, syntype, NMW 54092, Naturhistorisches Museum, Wien.

The mounted holotype of *Labeobarbus euphrati* is in the Muséum national d'Histoire naturelle, Paris (MNHN A.6961) and measures 1650 mm total length (Bertin and Estève, 1948). Eschmeyer *et al*. (1996) indicated that the catalogue number may be A.6971.

*Labeobarbus euphrati*, holotype, MNHN-IC-A-6961, S. Grosjean and M. Silvain (CC BY-NC-ND 4.0).

*Labeobarbus euphrati*, holotype, MNHN-IC-A-6961, S. Grosjean and M. Silvain (CC BY-NC-ND 4.0).

*Labeobarbus euphrati*, holotype, MNHN-IC-A-6961, S. Grosjean and M. Silvain (CC BY-NC-ND 4.0).

**Key characters.** This species is characterised by large size, a long, tapering and depressed head (rather pike-like in shape, hence the names), lateral line scale count high (62-78), moderately developed lips, and no large flank spots.

**Morphology.** The body is compressed and moderately deep being deepest at the level of the end of the pectoral fin. The predorsal profile is convex. A nuchal hump develops in some larger fish. The caudal peduncle is compressed and moderately deep. The head profile is rectilinear or slightly concave and is tapering. The eyes are tangent to the upper profile and are well anterior because of the long postorbital distance. The mouth is large, terminal to slightly subterminal, and almost horizontal and extends back to the anterior eye margin. Lips are thin to moderate and the lower lacks a median lobe to the interrupted lip. Barbels are slender, the anterior one reaching the anterior nostril level and the posterior one the anterior eye margin to posterior eye margin. Both barbels can be quite short, the anterior one reaching only half way to the base of the posterior one. The nostril is elongate and closer to the eye than the snout tip. The cephalic canals on the suborbital series have numerous branches. The dorsal fin margin is emarginate and perpendicular, or nearly so, to the back. The last dorsal fin unbranched ray is very strong with strong denticles over three-quarters to four-fifths of its length. The depressed

dorsal fin extends back to before, at or past the anal fin origin level. The dorsal fin origin is over or slightly behind the origin of the pelvic fin. The caudal fin is moderately forked with pointed to rounded lobes. The anal fin margin is straight and the fin does not reach back to the procurrent caudal fin rays. The pelvic fin is rounded and does not extend back to the anus. The pectoral fin is rounded and does not extend back to the pelvic fin. Some of the above is after Almaça (1986, 1991) based on 4 syntypes NMW 54088, 54091 and 54092.

Head length in standard length for Iranian material was 3.3-3.5, mean 3.4, postorbital length in standard length 5.4-6.1, mean 5.8, and postorbital length in head length 1.7-1.8, mean 1.7, for 3 specimens 203.8-299.8 mm standard length.

Dorsal fin unbranched rays 4 and branched rays 8, anal fin unbranched rays 3 and branched rays 5, pectoral fin branched rays 16-18, and pelvic fin branched rays 8. Lateral line scales 62-78. Scales are regularly arranged, the smallest being on the isthmus anterior to the pectoral fin bases. There is a pelvic axillary scale. Scale shape is squarish. Scales have a central or slightly subcentral anterior focus, numerous fine circuli, an anterior margin that is wavy, rounded or with a protruding central part indented above and below, gently rounded dorsal and ventral margins, a rounded posterior margin, and numerous radii on the anterior and posterior fields with a few widely spaced ones on the lateral fields. Total gill rakers number 8-12, well-spaced and just touching the one below when appressed (Jouladeh-Roudbar *et al*. (2020) gave 17-22). Pharyngeal teeth are 2,3,5-5,3,2, hooked with the third tooth of the inner row slightly larger than the fourth and the fifth smaller. Heckel (1843b) gave 2,3,4-4,3,2, and teeth from large specimens seen at Ahvaz in 1995 by me had 2,3,4-4,3,2 and 2,3,5-4,3,2, the anteriormost tooth being small or absent. Even small specimens (85.7 mm standard length) may have the anteriormost tooth absent. The gut is an elongate s-shape with several anterior loops. Total vertebrae number 48 (Howes, 1987) or 48-50 based on comparative materials shown above and the syntypes. The syntype NMW 54091 has 48 total vertebrae and the syntype NMW 54092 has 50 total vertebrae. Jouladeh-Roudbar *et al*. (2020) gave 43-49, the lower counts seeming unlikely.

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(3), anal fin branched rays 5(3), pectoral fin branched rays 16(1) or 17(2), pelvic fin branched rays 8(3), lateral line scales 67(1), 69(1) or 70(1), and total gill rakers 9(1), 10(1) or 11(1).

**Sexual dimorphism.** Unknown.

**Colour.** The back has numerous scattered, black spots on an olivaceous background, the spots extending onto the base of the dorsal fin. Spots may be weak or absent but this is comparatively rare. Overall colour is silvery with the anal and caudal fins dark grey to dark red. The flanks and belly are lighter and may be silvery, white or yellow. The iris is yellowish in colour. Young fish have a yellow tinge or sulphur yellow colour to the fins with the leading edge of the pectoral and pelvic fins immaculate yellow.

**Size.** The large size of this species has long been known. Such travelers as Buckingham (1829) recorded a fish large enough to form a good load for an ass and Budge (1920) recorded in the Tigris “an enormous fish, more than five feet long, and very thick, and it had a huge mouth”.

Frequently up to 3 hundredweights (= 152.4 kg) in the Zab River of Iraq southeast of Mosul (Heckel, 1847a); a fish 6'4" (1.93 m) long with a girth of 3'10" (1.17 m) and a weight of 215 lbs (97.6 kg) from the Euphrates River at Hakika (Light, 1917; wrongly identified as “*Barbus*” *scheich* (= *schejch*) according to the editors in an article by Gudger (1945)); 69 inches (1.75 m) measured over the curve of a back with a 38 inch (0.97 m) girth and a weight

of 123 lbs (55.8 kg) caught in the Diyala River, Iraq on a light 14-foot rod taking 1½ hours to land (Bagnall, 1919); 96 lbs (43.6 kg) fish caught near Kizil Robat (= As Sa`diyah) in the Diyala River on a lump of *atta* (a ball of dough) (MacKay, 1919) (Bagnall, a Major, out-doing MacKay, a Brigadier-General); 140 lbs (63.6 kg) "Tigris salmon" caught on a 2" spoon at Samarra (Lane, 1920); hundreds of good weight up to 112 lbs (50.8 kg), one caught on a hand-line at 170 lbs (77.2 kg), one netted at 252 lbs (114.4 kg), and reputedly over 300 lbs (136 kg) (Radcliffe, 1926); up to two yards (1.83 m) as evidenced by a photograph of a specimen draped over a donkey in Iraqi Kurdistan (Hamilton, 1937); 2 m and 150 kg in Iraq (van den Eelaart, 1954; Herzog, 1967); a 167 lbs (75.8 kg) Tigris specimen and a 213 lbs (96.7 kg) specimen at Nassiriyah on the Euphrates, called both gattan and "Euphrates salmon" but it was presumably the latter (Vesey-Fitzgerald and Lamonte, No date); weights up to 300 lbs (136 kg) and the largest taken on rod-and-line as 220 lbs (100 kg) and 7 feet (2.1 m), baits used included *atta* and dates, and chicken or sheep liver (Mahdi, 1962). Beck (pers. comm., 2000) reported the largest fish seen in the 1990s along the Syrian Euphrates and its tributaries weighed 198 kg. A fish caught in 2001 on the Euphrates River near Birecik in Turkey with a net weighed 111 kg and was 2.4 m long (www.fishing-worldrecords.com, downloaded 16 February 2007).

Iranian records of large specimens include one by Mr. Chabok-Savar, a Game Warden or biologist of the Department of the Environment who caught a specimen about 80 kg in the Simareh River in 1973 and N. Atarody, also a Game Warden or biologist, who caught two large specimens in April 1987 from Tang-e Gheer on the Simareh near Darreh Shahr (*Abzeeyan*, Tehran, 3 (August-September):19, 1992). A 1.65 m and 75 kg specimen was reported from the Dez River and a 2.1 m specimen was reported from the market at Ahvaz in 1993 (this last fish may have weighed 150 kg, original report not seen; J. Valiallahi, pers. comm., 2001). The Gamasiab, a river in Kordestan, is reputedly named for these large fishes ("river with fishes as large as a cow") (J. Valiallahi, www.modares.ac.ir, downloaded 4 July 2000). Floor (2003) gave a photograph of a large specimen from the Karun River.

**Distribution.** This species is found in the Tigris-Euphrates basin including its Iranian portion and the adjacent northern Persis basin. In the Persis basin recorded from the Zohreh River; in the Tigris River basin it is reported as common in the Dez Dam and is found in such rivers as the Arvand, Cham Ghorah, Dez, Dinvar, Gamasiab, Jarrahi, Kahnak, Karkheh, Karun, Qareh Su, Razavar (= Raz Avar), Shur, Simareh and Sirvan as well as the Hawr al Azim, Shadegan Marsh, Musa Estuary and the Gamasiab, Karkheh and Marun dams (Marammazi, 1995; Abdoli, 2000; Gh. Eskandary, pers. comm., 2000; Eskandari *et al*., 2007; Masoumian *et al*., 2008; Biokani *et al*., 2011; Khoshnood, 2014; Raeisi Sarasiab *et al*., 2014; Reyahi-Khoram *et al*., 2014; Taghavi Niya and Velayatzadeh, 2015; Khamees *et al*., 2019).

**Zoogeography.** Almaça (1984b, 1991) considered that the origin of this species lies with a group that migrated southwards in the late Pliocene from the Dacian Lake of the Sarmatian Sea and speciated in Mesopotamia. See also under the genus.

**Habitat.** This species is found in rivers, streams, lakes, dams, ponds, marshes and brackish environments. Found in large rivers and dams but also the more limited environment of palace ponds at Baghdad (see cover of Coad (2010)). Fingerlings may be found in marshes (van den Eelaart, 1954). Izadi *et al*. (2013) found fish in the Gamasiab, Qarasu (= Qareh Su) and Razavar (= Raz Avar) rivers at downstream stations with beds of sand and pebble-sand and slow current. Details of environmental requirements are unknown.

**Age and growth.** Life span is at least 10 years (Ahmed, 1982). Fish in Khuzestan were found to have a male:female sex ratio of 4.2:1 (Gh. Eskandary, pers. comm., 2000; Eskandari

*et al*., 2004). In the Dez Dam of northern Khuzestan, of 607 fish examined females had a length range of 156-1,350 mm and a weight range of 31.7-26,500 g while for males figures were 183-1,065 mm and 48-12,208 g. Males matured faster than females, annual growth was slow and asymptotic length was more than 2 m. It appeared to have a longer reproductive life compared to pre-maturation life (Eskandari *et al*., 2004). Hedayati *et al*. (2016a) examined 170 fish 19.4-42.2 cm total length from the Gamasiab River (or Reservoir) and found a *b* value of 2.871 (2.6546 in the summary). Hajiahmadian *et al*. (2018) evaluated 162 fish from the Gamasiab River and found male and female individuals comprised 54.76% and 45.24% respectively attributed to differential fishing factors rather than a real population sex ratio, age structure was between 1 and 5 years, the most frequent numbers for males and females belonged to the 2 and 4 age groups respectively, the length-weight relationship was $W = 0.0004TL^{2.3959}$ for males, $W = 3E\text{-}05TL^{2.81}$ for females and $W = 8E\text{-}05TL^{2.6546}$ for all individuals (all negative allometric growth), mean total length and weight were 33.38 cm and 297.67 g for males, and 37.15 cm and 307.85 g for females, the von Bertalanffy growth models were $L_t = 357.14x[1\text{-}e^{(-0.77x(t\ -0.090))}]$ for males, $L_t = 367.02x[1\text{-}e^{(-0.78x(t\ -0.094))}]$ for females and $L_t = 363.57x[1\text{-}e^{(-0.76x(t\ -0.087))}]$ for both sexes, growth factors were highly similar in spring, summer and winter, maximum growth rates were observed at early ages (1-2 years) and declined with age, the growth coefficient (K) was 0.77 $Y^{-1}$ for males and 0.78 $Y^{-1}$ for females showing sex did not affect growth rate, $L_\infty$ was 35.71 cm for males and 36.7 cm for females showing perhaps a longer lifetime in females, and condition factor was lowest in spring for both sexes, highest in autumn for males and winter for females.

Çoban *et al*. (2012) studied 187 fish in the Keban Dam in Turkey and found a maximum age of 17 years, with most fish at age 4 years, an equal sex ratio, a length-weight equation for all fish of $W = 0.0057TL^{3.2187}$showing positively allometric growth, and growth parameters $L_\infty$ = 225.621 cm, k = 0.031, $t_0$ = -3.929 for males, $L_\infty$ = 234.378 cm, k = 0.038, $t_0$ = -2.819 for females, and $L_\infty$ = 229.732 cm, k = 0.035, $t_0$ = -2.891 for all individuals, and condition factor increased until age 5 and then decreased. Dartay and Gül (2014) however, found a length-weight relationship for 22 Keban Dam fish (37.4-49.7 cm total length) of $W = 0.0101L^{2.915}$.

**Food.** This species is a predator on other fishes. In the Dez Dam, all samples had fish in their stomachs although the gut to body length ratio indicated omnivory (Eskandari *et al*., 2004). Al-Rudainy (2008) cited also crustaceans, aquatic insects and zooplankton in Iraq, presumably including younger fish.

**Reproduction.** Eskandari *et al*. (2004) reported a very short spawning season in the Dez Dam in spring after reservoir water levels rose through spring flooding. The fish was a total spawner with eggs released in upstream areas and shallows of the reservoir over gravel at 24ºC. Hajiahmadian *et al*. (2018) found Gamasiab River fish had the highest gonadosomatic indices in spring for females and winter for males, decreasing rapidly after spring in females. Spawning took place in spring when condition factor was lowest and gonadosomatic index highest, with fast growth in autumn in preparation.

van den Eelaart (1954) reported spawning in Iraq in March and Al-Rudainy (2008) gave April to May. Çoban *et al*. (2012) found Keban Dam, Turkey fish to have the highest gonadosomatic indices in March, and March-April was the spawning season. Eggs were laid between large stones in the deep part of rivers, with absolute fecundity in Iraq at 600,000 eggs (Al-Rudainy, 2008). Some fingerlings drifted down into lakes and marshes. Ünlü (2006) gave age at first maturity as 4 years in the Turkish Tigris River while Al-Rudainy (2008) gave

sexual maturity as 10 years in Iraq.

**Parasites and predators.** Masoumian *et al*. (2008) recorded the myxosporeans *Myxobolus karuni* and *M. persicus* from gills of fish captured in the Karun and Karkheh rivers and Shadegan Marsh.

**Economic importance.** This species was considered for aquaculture during the year 2000 in Khuzestan although fish larger than 1 m are needed to be ripe adults. Anglers and commercial fishermen seek this fish in the Iranian Zagros Mountains using ducklings (!) as bait (J. Valiallahi, pers. comm., 2001). Poria *et al*. (2013) noted that it is important as a commercial and sport fish in the Gamasiab River in Kermanshah Province. This species is angled for in Turkey and Iran particularly and various photographs and videos of it may be found online. Hajiahmadian *et al*. (2018) mentioned it is caught commercially in the Gamasiab River.

In Iraqi Kurdistan, these fish were caught and tethered by a cord passed through the lips until eaten by the villagers (Elliot, 1977). At Altan Keupri on the Lesser Zab River in Iraq, drugged bait was used to stupefy the fish so it could be netted and dragged to shore (Hamilton, 1937). It is fished for in Turkey for sport and food and numerous images of large specimens caught on-line or for sale in fish markets can be seen on the internet.

Robins *et al*. (1991) listed this species as important to North Americans. Importance was based on its use in textbooks.

**Experimental studies.** Alishahi *et al*. (2016) found the $LC_{50}$ 96 h of the herbicides paraquat, 2,4-dichlorophenoxy acetic acid, trifluralin, glyphosite (*sic*, presumably glyphosate) and atrazine in fingerlings were 54.66, 138.8, 1.09, 716.83 and 44.30 mg/l respectively, and recommended glyphosate in the sugar cane farms of Khuzestan. Silavi *et al*. (2017) carried out spawning induction studies on female brood stock and recommended a three-stage injection process with 7 μg/kg of LHRH-$A_2$ hormone as a preliminary followed by two injections of pituitary gland extract, 0.5 mg/kg and 4.5 mg/kg. The response rate was 100%, working fecundity was 257,240 eggs, fertilisation rate was 96.3%, hatching rate 97.0%, and larval rate 240,400.

Özgür *et al*. (2016) characterised the embryonic and larval development of wild fish from the Karasu River of the upper Euphrates River basin in Turkey as preliminary data on the possibility of breeding this species through artificial insemination and to determine the incubation period at different temperatures of hatchery water.

**Conservation.** This species is under severe threat in the Syrian Euphrates and its tributaries. A survey in 1997-1998 caught only a single juvenile and the commercial fisheries had not more than two dozen fish. Blast fishing and poisoning had led to a decline in age of catches since 1993. Large scale water abstraction, dam building and pollution had destroyed habitats (R. Beck, pers. comm., 2000). It was listed by Stone (2007) as one of the world's largest freshwater fishes, presumed to be threatened. Smith *et al*. (2014) listed it as Vulnerable, overfishing being the principal threat. Listed as Vulnerable by the IUCN (2015) through overfishing and dam construction blocking access to spawning sites. However, large populations can survive in reservoirs. Freyhof *et al*. (2020) considered it to be threatened mostly by overfishing, but also by water abstraction, pollution and dam construction, blocking migrations and destroying riverine habitat due to reduced discharge. Although it adapts to man-made lakes when introduced, it is likely that reproductive success is inhibited under such conditions.

It is an iconic species and part of a world survey to assess the status of large freshwater fish species by the Word Wildlife Fund and the National Geographic Society

(http://news.nationalgeographic.com/news/2004/12/1214_041214_huge_fish_2.html, downloaded 14 April 2015).

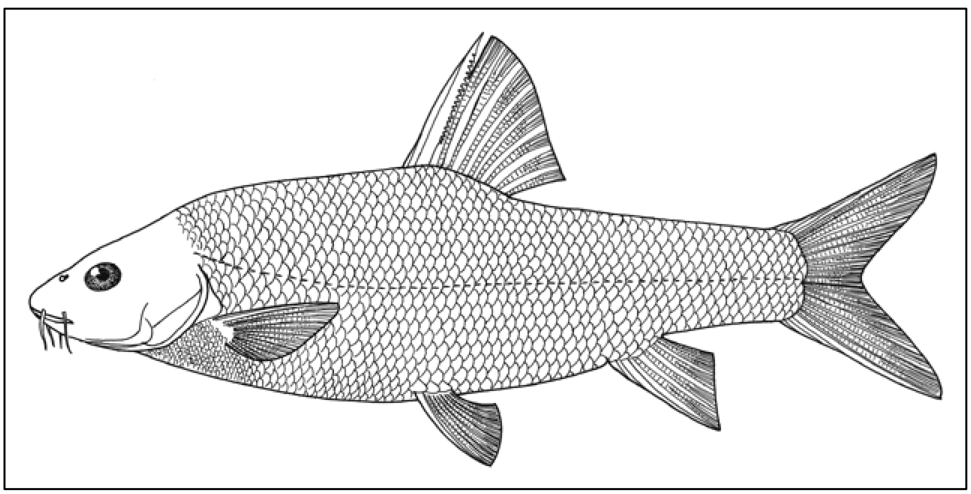
A report of a fish kill, presumably of this species, in the Cham Ghorah River near Mahabad in July 1999 numbering about half a million fish was owing to desiccation of the habitat (J. Valiallahi, www.modares.ac.ir, downloaded 4 July 2000). Izadi *et al*. (2013) fished the Gamasiab, Qarasu (= Qareh Su) and Razavar (= Raz Avar) rivers at 10 stations each for 12 months and caught 13, 6 and 4 fish respectively. The fish were 21-96 cm and 126-19,450 g. Repeated droughts, pollution and overfishing had severely damaged stocks.

**Sources.** Type material:- *Luciobarbus esocinus* (NMW 54088 and SMF 454).

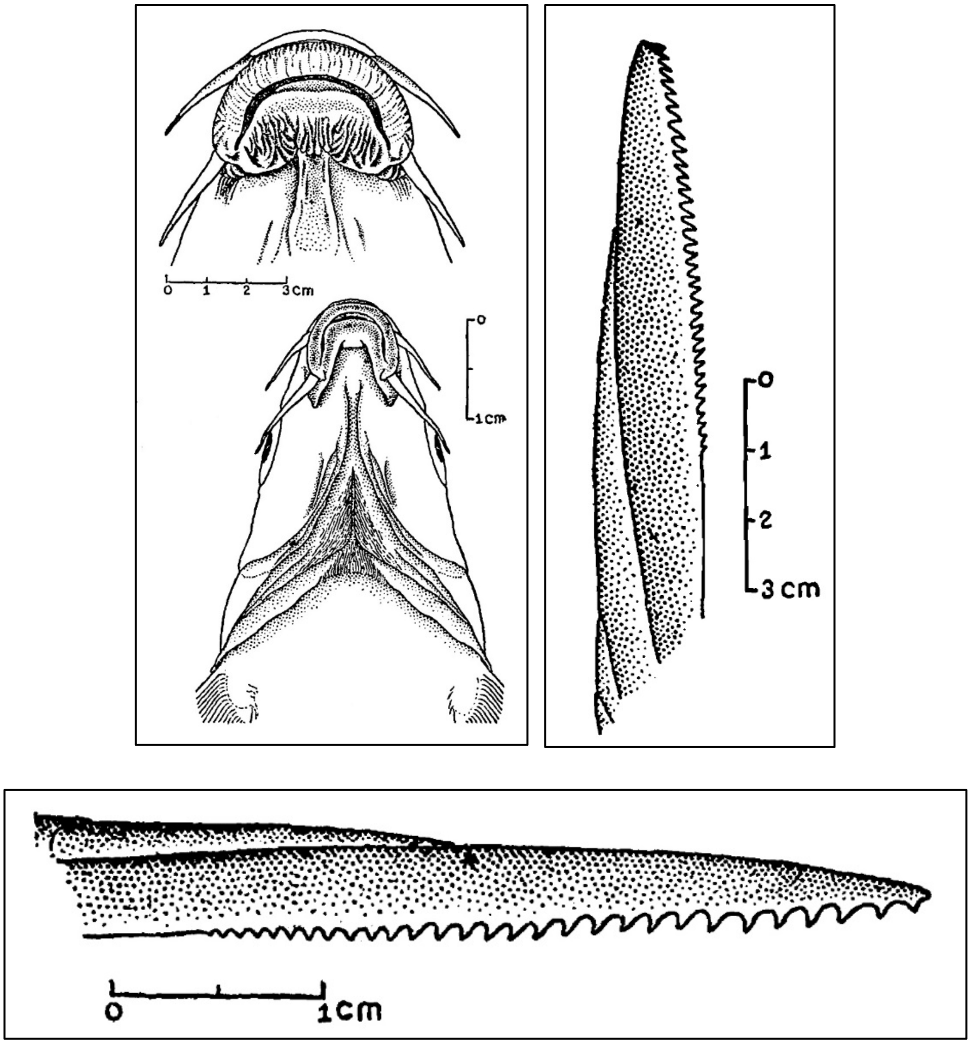
Iranian material:- CMNFI 2008-0132, 1, 299.8 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); CMNFI 2008-0151, 1, 203.8 mm standard length, Kermanshah, Gamasiab River (34º10'44"N, 47º20'48"E); ZSM 21830, 1, 284.3 mm standard length, Khuzestan, Dez River at Harmaleh (31º57'N, 48º34'E). Some specimens observed in the IFRTO laboratory at Ahvaz (pharyngeal arches, head).

Comparative material:- BM(NH) 1892.9.1:30, 1, 197.3 mm standard length, Iraq, Al Faw (29º58'N, 48º29'E); BM(NH) 1920.3.3:80-82, 3, 85.7-147.0 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1931.8.12:5, 1, 111.8 mm standard length, Iraq, near Mosul (ca. 36º20'N, ca. 43º08'E); BM(NH) 1974.2.22:1297, 1, 166.5 mm standard length, Iraq, Diyala River (no other locality data); BM(NH) 1974.2.22:1810, 1, 220.1 mm standard length, Iraq (no other locality data.

## *Luciobarbus kersin*
(Heckel, 1843)



*Luciobarbus kersin*
Susan Laurie-Bourque @ Canadian Museum of Nature.




*Luciobarbus kersin*, ventral heads, from fish 70.1 cm above and 36.7 cm total length below, with dorsal fin spines of each to left and below, Iraq, Tigris River, after Menon (1960), and see comments below.

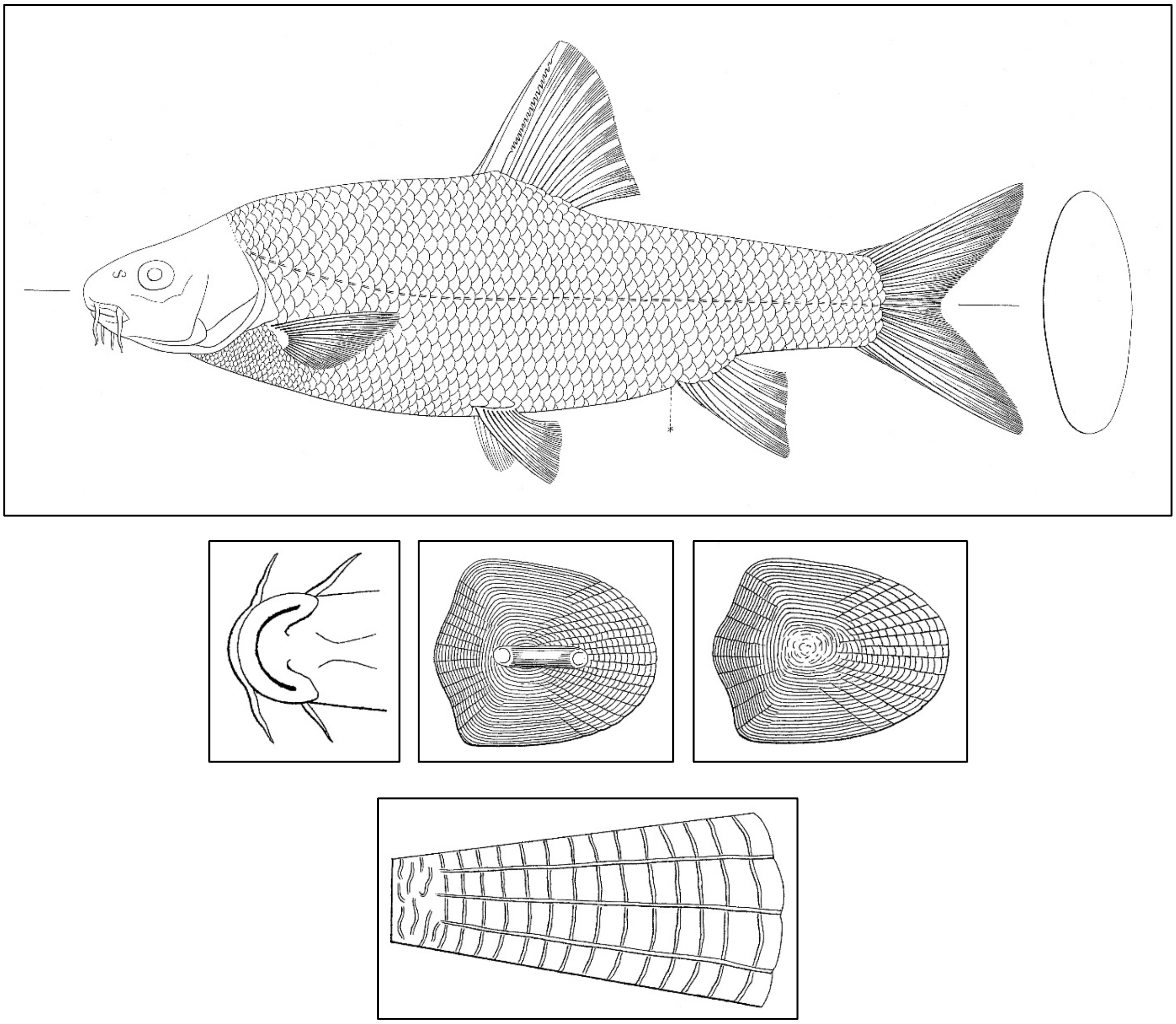
*Luciobarbus kersin*, Khuzestan, Hawr al Azim, after Jouladeh-Roudbar *et al*. (2020).

**Common names.** Berzem, berzom pahn, dabe dogh.

[Shissan, djissan, gassan, gazzan, jassan (perhaps from the root j-s-s meaning to explore, hence jassan, an explorer) (Mikaili and Shayegh, 2011), kersin at Aleppo (perhaps from karsin (meaning paunchy, gluttonous) and karsana (meaning pot-bellied) (Mikaili and Shayegh, 2011)), barsam or bunni, all in Arabic; Kersin balığı in Turkish (Çiçek *et al*., 2020); kersin barbel].

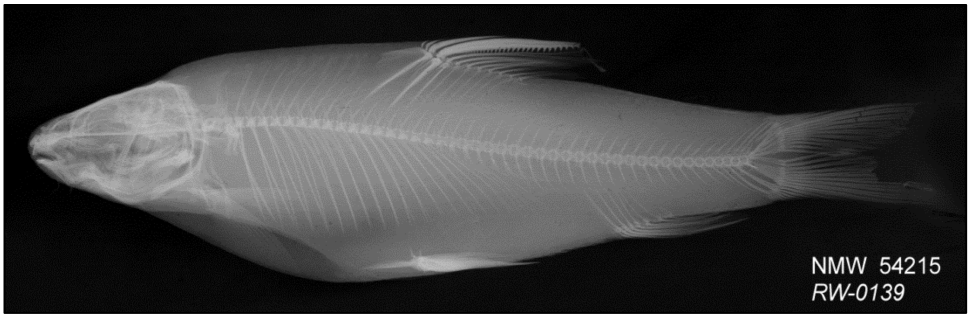
**Systematics.** Karaman (1971) placed this species as a synonym of his *Barbus capito pectoralis*. Almaça (1983) suggested that *kersin* may be only subspecifically distinct from *Barbus* (= *Luciobarbus*) *pectoralis* but later (Almaça, 1984b) retained it as a full species until further information became available. Krupp (1985c) also synonymised this species with *Barbus* (= *Luciobarbus*) *pectoralis*. Dustdar and Ramin (2016) did not recognise this taxon as present in Iran.

Syntypes of *Barbus Kersin* from "Aleppo", the type locality given by Heckel (1843b) or "Gewässern von Aleppo" (Heckel, 1847a), are in the Naturhistorisches Museum Wien (NMW 54212 and NMW 54215) (Almaça, 1986). Krupp (1985c) listed the following syntypes of *B. kersin* all from Aleppo, 1, 141.2 mm standard length as measured by me (NMW 54212), 4, 89.1-135.1 mm standard length as measured by me (NMW 54213), 1, 166.0 mm standard length as measured by me (NMW 54215) and 1, 152 mm standard length (formerly NMW, now in the Senckenberg Museum Frankfurt as SMF 610). The card catalogue in 1997 listed NMW 54215 as "? Lectotype" and NMW 54213 as "? Paralectotypes" (*sic*). Eschmeyer *et al*. (1996) listed one syntype in the Museum für Naturkunde, Universität Humboldt, Berlin (ZMB 3237, formerly NMW). The catalogue in Vienna listed six specimens.



*Barbus kersin*,
body and cross-section, ventral head, lateral line scale, flank scale from between the dorsal fin and lateral line, and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Luciobarbus kersin*, syntype, NMW 54215, Naturhistorisches Museum, Wien.



*Luciobarbus kersin*, syntype, NMW 54215, Naturhistorisches Museum, Wien.

Khaefi *et al*. (2017, 2018) reported on hybrids with *L. barbulus* in the Iranian Tigris River basin.

**Key characters.** This species has the deepest body of these *Luciobarbus* species in Iran, the lips are not markedly fleshy, and the fourth major row pharyngeal tooth is not molariform.

**Morphology.** The body is very deep, the deepest of all the species surveyed by Almaça (1984b**).** Body depth is equal to or greater than head length in the types examined by me. The body is also rounded and deepest in front of the dorsal fin. The head profile is rectilinear or slightly convex and depressed forward of the nostrils. The highly rounded snout projects a little. The caudal peduncle is compressed and deep. The rear of the eye is at the beginning of the anterior half of the head. The mouth is subterminal, lips are thin to moderately thick but not fleshy, and there is no median lobe on the lower lip. Material from Iraq identified as *L. kersin* by Menon (1960) (see figures above, fish not seen by me) have size-related variation in mouth shape but there may be confusion with other species. The upper lip is partly covered by the snout. The barbels are slender with the anterior one reaching the nostril level or the anterior eye margin and the posterior reaching the anterior eye margin or the middle of the eye level. The dorsal fin margin is emarginate and almost perpendicular to the back. The last unbranched dorsal fin ray is strong with strong denticles extending two-thirds to three-quarters its length. The depressed dorsal fin reaches back to, or falls short of, the level of the anal fin origin and the dorsal fin origin is over or slightly behind the pelvic fin origin. The caudal fin is deeply forked with rounded tips. The anal fin has a straight margin and does not reach back to the caudal fin procurrent rays. The pelvic fin has a rounded margin and is remote from the anus. The pectoral fin has a rounded margin and is remote from the pelvic fin. Above in part after Almaça (1986) based on two syntypes, NMW 54212 and NMW 54215.

Dorsal fin unbranched rays 3-4, usually 4, branched rays 7-8, usually 8, anal fin with 3-4 branched and 5-6, usually 5, unbranched rays, pectoral fin branched rays 16-18, usually 17, and pelvic fin branched rays 7-10, usually 8. Lateral line scales 49-58. Scale shape is a somewhat rectangular with a rounded posterior margin and gently rounded dorsal and ventral margins. The anterior margin has a central protrusion and very shallow indentations above and below. The anterior scale corners are fairly abrupt but rounded. The focus is slightly subcentral anterior and circuli are quite coarse. Radii are present on the anterior and posterior fields and are quite numerous. Total gill rakers number 19-23 (Khaefi *et al*. (2018) gave 16-18, perhaps lower arm rakers only), stubby anteriorly and only slender at the junction of the upper and lower arms of the arch, reaching just past the one below when appressed or to the second raker below. Pharyngeal teeth are 2,3,5-5,3,2. The anterior tooth is thickened and rounded, the next less so and the remainder have a hooked tip with a scalloped area below. Total vertebrae

number 43-47. A syntype of *L. kersin*, NMW 54215, has 47 vertebrae.

**Sexual dimorphism.** Unknown.

**Colour.** The body lacks distinctive markings and is olive to reddish-brown to golden above, silvery on the flanks and white below. Scales are outlined in dark brown on the upper flank, becoming lighter on the lower flank but still outlined. The dorsal and caudal fins have a blackish margin. The caudal fin rays and membranes are dark brown. The dorsal and anal fins are also dark but not as dark as the caudal fin. The pectoral and pelvic fins are dark distally and on the anterior rays.

**Size.** Attains 70.1 cm total length (Menon, 1960) and 5.0 kg (van den Eelaart, 1954). Reaches 2.0 m and over 100.0 kg (Khalaf, 1961), possibly confused with larger species.

**Distribution.** This species is found in the Tigris-Euphrates and adjacent Persis basin, and the Quwayq and Orontes River basins. In Iran, it is found in the Persis and Tigris River basins. In the northern Persis basin in the Helleh and Zohreh rivers and questionably the southern Persis basin; and in the Tigris River basin in the Alvand, Arvand, Dez, Karkheh, Karun and Marun rivers, the Marun Dam, and the Hawr al Azim and Shadegan wetlands (Abdoli, 2000; Gussev *et al*., 1993a; Khaefi *et al*., 2018; Fatemi *et al*., 2019; Khamees *et al*., 2019).

The record from Rudan County in the eastern Hormuz basin (Shahi *et al*., 2015) is presumably an error.

**Zoogeography.** Almaça (1984b, 1991) considered that the origin of this species lies with a group that migrated southwards in the late Pliocene from the Dacian Lake of the Sarmatian Sea and speciated in Mesopotamia.

**Habitat.** This species is found in rivers, streams, lakes, dams and marshes. The main habitat of Iraqi fish is rivers, entering marshes and lakes during floods but returning to rivers in June (van den Eelaart, 1954). It is also found in artificial reservoirs on dammed rivers.

**Age and growth.** Unknown.

**Food.** This species is said to eat a wide range of food items (Beckman, 1962), including aquatic insects and plants (Al-Rudainy, 2008).

**Reproduction.** Eggs are deposited on clay or gravel bottoms during mid-February to early March in Iraq (van den Eelaart, 1954). Al-Rudainy (2008) gave the spawning season as March to April in Iraq.

**Parasites and predators.** Gussev *et al*. (1993a) described new species of monogeneans from this species in the Dez River, Khuzestan, namely *Dactylogyrus deziensis*, *D. deziensioides* and *D. kersini*. Ebrahimzadeh and Kailani (1976) recorded parasite species in the cestode genera *Caryophyllaeus* and *Isoglaridacris* and the protozoan *Myxosoma* from fish taken in the Karun River.

**Economic importance.** van den Eelaart (1954) reported fishing seasons in Iraq in January-March (peaking in February) and June-November (peaking in July) in rivers and March-July (peaking in mid-May to mid-June) for lakes and marshes.

**Experimental studies.** None**.**

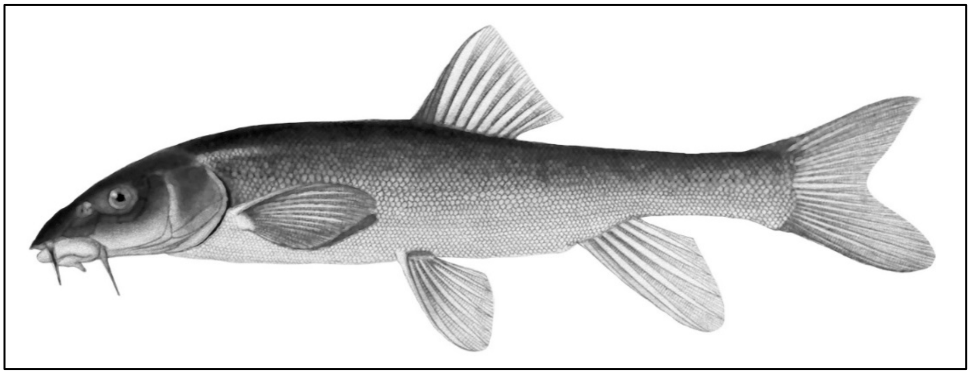
**Conservation.** Endangered in Turkey (Fricke *et al*., 2007) but status in Iran unknown. Listed as Data Deficient by the IUCN (2015).

**Sources.** Type material:- *Barbus kersin* (NMW 54212, NMW 54213 and NMW 54215).

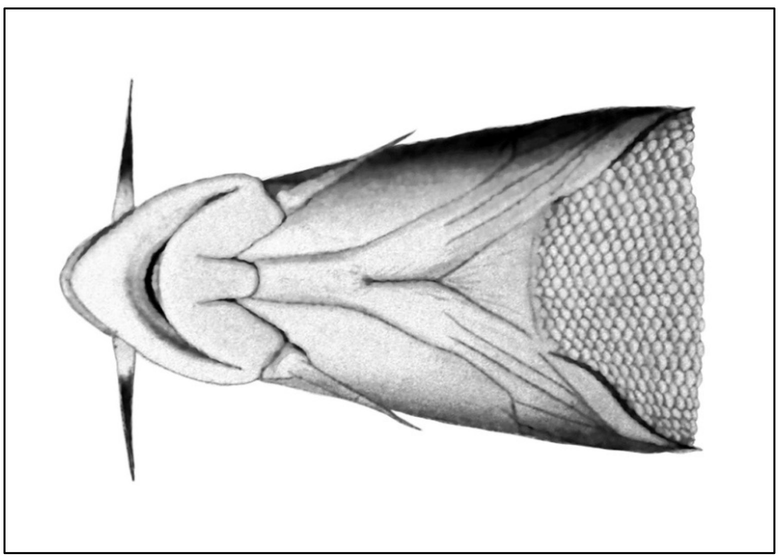
Iranian material:- CMNFI 2008-0132, 1, 257.1 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data).

Comparative material:- BM(NH)1920.3.3:41-50, 12(5 examined), 110.9-165.3 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH)1920.3.3:31-40, 10, 141.7-310.9 mm standard length. Iraq, Basrah (30º30'N, 47º47'E); BM(NH)1974.2.22:1324, 186.2 mm standard length, Iraq, Baghdad (33º21'N, 44º25'E).

## ***Luciobarbus mursa***
(Güldenstädt, 1773)



*Luciobarbus mursa*, 34.8 cm total length, ZISP 9934,
Georgia, Kura River at Borzhom (= Borjomi), after Berg (1948-1949).



*Luciobarbus mursa*, as above, after Berg (1948-1949).

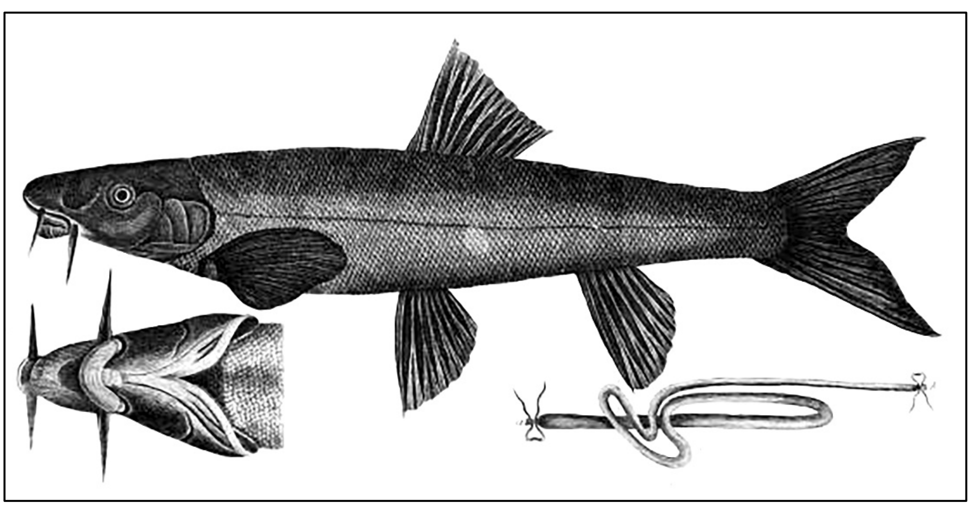
*Luciobarbus mursa*, Iran, Aras River, 2 October 1994, Asghar Abdoli.

*Luciobarbus mursa*, Iran, Aras River, July 2011, Keyvan Abbasi.

**Common names.** Sas, sass or sos mahi, mahi siah (= black fish), sas mahi-ye lab koloft (= thick lip "*Barbus*" fish), ses mahi koloft sefid rud (= Sefid River thick "*Barbus*" fish, the meaning of sas, ses or sos being unknown but referring to "*Barbus*"), zardek-e qalami (= slender or straight yellow one), zardehpar (in reference to yellow fins).

[Mursa or shchirbit in Azerbaijan; mursa or murtsa in Georgian; Murzu in Turkish (Kaya *et al*., 2020); murtsa or Araksinskaya murtsa, both in Russian; mursa barbel, thicklip barb].

**Systematics.** *Cyprinus mursa* was originally described from the Kura River at Tbilisi, Georgia. Syntypes are presumed lost (Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003). Synonyms are *Barbus mursoides* Kessler, 1877 described from Transcaucasia (presumably the Kura-Aras basin) and *Barbus microphthalmus* Sauvage, 1882 from "Tiflis" (presumably the Kura River at Tbilisi, Georgia). *Barbus macrophthalmus* and *Barbus mycrophtalmus* in Chantre (1882) are presumably misspellings of *Barbus microphthalmus*; the former is in any case preoccupied by *B. macrophthalmus* Bleeker, 1855 described from Indonesia; additionally, independent of *Barbus microphthalmus* Bonaparte, 1846, a name in synonymy in Europe, but use by Sauvage makes *Barbus microphthalmus* Bonaparte 1846 an available name. Sauvage's *Barbus microphthalmus* is therefore preoccupied and objectively invalid. Dadikyan (1986) referred Aras River fish from Armenia to *Barbus mursa mursoides*.



*Cyprinus mursa*, syntype, after Güldenstädt (1773).

The holotype of *Barbus mursoides* is in the Zoological Institute, St. Petersburg (ZISP 2863) from the Caucasus collected by Hohenacker in 1838.

Two syntypes of *Barbus microphthalmus*, one measuring 340 mm total length, are in the Muséum national d'Histoire naturelle, Paris (MNHN A.3923, formerly MNHN 1881-1007 and MNHN 1881-1008) (Bertin and Estève, 1948).


*Barbus microphthalmus*, syntypes, MNHN IC A.3923, L. Randrihasipara (CC BY 4.0).

**Key characters.** The high lateral line scale count (74-106) and the presence, usually, of a fleshy three-lobed lower lip, are characteristic.

**Morphology.** The body is elongate and rounded with a long head. The back in front of the dorsal fin is rounded, not compressed, and is gently convex or straight. The body is deepest over the pelvic fins. The head profile is convex or straight and there may be a groove anterior to the nostrils. The predorsal distance is longer than the postdorsal distance. The caudal peduncle is compressed and shallow. The head and snout are elongate and tapering, with the snout tip rounded. The eye is positioned mid-head. The mouth is moderate in size, inferior and horseshoe-shaped, and the fleshy lips are moderate to thick, wrinkled or tuberculate, with a lower lip median lobe. The three lobes are tuberculate. The median lobe may be undeveloped in some fish to strongly developed in others. Larger specimens may have the lower (and sometimes the upper) jaw with a thin horny padding. The barbels are thin to thick with the anterior one reaching back to the nostril level or second barbel (or to the rear of the nostril and overlapping the beginning of the second barbel) and the posterior one to the middle of the eye or the rear eye margin. The dorsal fin margin is slightly concave and oblique or perpendicular to the back. The last unbranched dorsal fin ray is a strong spine with strong, closely-packed, slender denticles in adults, one-half to four-fifths of the spine length, although denticles are lost in some adults, and denticles are weaker in young. The depressed dorsal fin reaches back to the anal fin origin level or falls short of it. The dorsal fin origin is slightly behind the pelvic fin origin. The caudal fin fork is moderate and the tips are rounded or pointed with the ventral lobe often larger and more rounded. The anal fin margin is rounded or slightly emarginate and the fin may, or may not, extend back to the procurrent caudal fin rays. The pelvic fin is rounded to straight and remote from the anus. The pectoral fin is rounded to slightly emarginate and does not extend back to the pelvic fin origin.

Dorsal fin unbranched rays 3-5, usually 4, followed by 7-8, usually 8, branched rays, anal fin unbranched rays 3 followed by 5 branched rays, pectoral fin branched rays 13-17, and pelvic fin branched rays 6-8, usually 7. Lateral line scales 74-106, often 85 or more. A single

pelvic axillary scale is not developed but a series of enlarged scales may be separated from other scales by a fold of skin. Scales are small, horizontally elongated and almost rectangular, with an anterior margin variably indented, a very anterior focus, relatively few and well-spaced circuli, and few radii on all fields. Gill rakers number 7-18 (10-18 in Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya (2003), lower counts from the literature perhaps not including rakers on the upper arm of the arch, but see below where total counts are 9-16. There may also be differences due to size and, independent of size, the rakers on the lower arch anteriorly are variably developed, sometimes being reduced to bumps which were counted and sometimes not even bumps are present. The larger rakers reach the second adjacent raker when appressed. Pharyngeal teeth are usually 2,3,5-5,3,2, rarely 1,2,3,5-5,3,2,1; or with only 4 teeth in the main row (e.g., see Heckel (1843b)). Teeth are hooked and the fourth inner row tooth is slightly larger or smaller than the third. The fifth tooth is smaller (sometimes minute) than teeth 3 and 4 and may be pointed or blunt. The grinding surface below the tip of main row teeth is short, uneven and concave to rounded. The gut is elongate with 2-3 anterior loops. Total vertebrae number 41-45. Chromosome number 2n = 100, NF = 140 (Pourali Darestani *et al*., 2006).

Meristic variation in Iranian specimens:- dorsal fin branched rays 7(1) or 8(15), anal fin branched rays 5(16), pectoral fin branched rays 16(13) or 17(3), pelvic fin branched rays 7(13) or 8(3), lateral line scales 80(1) …., 84(1), 85(1), 86(-), 87(1), 88(3), 89(3), 90(3), 91(1), 92(1) …. or 95(1), total gill rakers 9(1) …., 12(1), 13(5), 14(4), 15(2) or 16(3), pharyngeal teeth 2,3,5-5,3,2(7), 2,3,4-5,3,2(5) or 2,3,5-4,3,2(2), and total vertebrae 43(1), 44(6) or 45(2).

**Sexual dimorphism.** A female specimen, 112.5 mm standard length, caught on 15 July 1962 (CMNFI 1980-0132) had tubercles on the top and upper sides of the head. Male tuberculation in large adults has not been reported on.

**Colour.** Overall colour is a pale grey to olive-grey to brownish or reddish, slightly darker to much darker over the back, and the belly is white to yellowish-brown. The sides of the head and flanks can have golden tints. The iris is grey with a narrow rim of silver immediately around the pupil or may be yellow-gold. The thick lips may be reddish. The dorsal and caudal fins are pale grey to dark reddish-brown. The caudal fin bears several series of small dark spots. The pectoral and pelvic fins have pale brown rays and transparent membranes but may be yellowish, pink or dark red. The anal fin may be colourless except for a little grey pigment over the last unbranched and first branched rays to an overall reddish-brown. The margins of the pelvic and anal fins are well-developed and white, while the pectoral fin has a very narrow white margin. Young may have numerous dark spots on the back and upper flank, lost in adults.

**Size.** Attains 39.5 cm (Berg, 1948-1949) or 43.0 cm total length (Naderi Jolodar and Abdoli, 2004).

**Distribution.** This species occurs in the Caspian Sea and Lake Urmia basins. It is found in the Kura River basin of the southwestern Caspian Sea and in southern tributaries of the Caspian Sea. In Iran, it is reported in the Caspian Sea basin including the Alamut, Aras, Babol, Balekhlu, Chalus, Dogh, Gorgan, Haraz, Kalibar, Lisar, Madar Su, Polrud (= Pol-e Rud), Qareh Su, Qezel Owzan, Sardab, Sefid, Shah, Shirud, Shurab, Tajan, Talar, Taleghan (= Taleqan), Tonekabon, Valam and Zarem rivers, the Nazdik Dam on the Sefid River and the Sattarkhan Dam on the Ahar Chay in East Azarbayjan; and in the Lake Urmia basin in the Arnar Chay, Nowruzlu Chay, Simineh, Sophichay and Zarrineh rivers (Günther, 1899; Kiabi *et al*., 1994, 1999; Abbasi *et al*., 1999; Abdoli, 2000; Pazooki *et al*., 2003; Aghili *et al*., 2008;

Abdoli and Naderi, 2009; Hajirostamloo, 2009; Piri *et al*., 2009; Rahmani *et al*., 2013; Abdoli *et al*., 2014; Ghasemi *et al*., 2015; Khaefi *et al*., 2017; Aazami and Alavi Yeganeh, 2021).

**Zoogeography.** See under the genus above.

**Habitat.** This species is found in rivers, streams, pools, lakes, dams and brackish environments. It avoids muddy bottoms in streams with rapid water, preferring gravel and sand bottoms and a rich benthos according to Solak (1977) and Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya (2003). Collection data included a temperature range of 17.8-22ºC, pH 6.0, conductivity 0.5-0.65 mS, river width 6-60 m, medium to fast current, cloudy water, mud, clay, sand, or pebble bottoms, encrusting vegetation, and a grassy shore.

**Age and growth.** Esmaeili *et al*. (2014) gave a *b* value for 30 fish from the Iranian Caspian Sea, 5.6-21.6 cm total length, as 2.98. Aazami *et al*. (2015b) gave a *b* value of 2.91 for 77 fish, 4.08-9.05 cm total length, from the Tajan River. Mouludi-Saleh *et al*. (2021) examined 58 fish, 5.4-24.3 cm total length, from the Sefid River and recorded a *b* value of 3.09, isometric growth, and a condition factor of 0.82.

Solak (1989b) reported a life span of 6 years in the Aras basin of Turkey. Maturity is attained at 2-3 years (Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003).

**Food.** Food items include chironomids, as much as 70-100% of the diet at times, crustaceans such as copepods and ostracods, insects, worms, plankton, vegetation and detritus (Abdurakhmanov, 1962; Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003). Iranian fish guts contained plant fragments, aquatic insects such as chironomids and Ephemeroptera (mayflies), and crustaceans such as amphipods.

**Reproduction.** A fish caught on 6 July 1978 (CMNFI 1979-0481) had large, possibly atretic, eggs measuring about 1.5 mm although Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya (2003) reported a maximum egg diameter of 2.5 mm. Fecundity is up to 25,000 eggs. The spawning season is probably in May and June as noted for Georgian fish in Abdurakhmanov (1962) but may extend from April to August, the peak depending on locale (Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003).

**Parasites and predators.** Masoumian *et al*. (2003) recorded *Myxobolus azerbajdzanicus*, *M. kovali*, *M. osmaniae*, *M. rutili*, *M. squamae* and *M. tauricus* while Pazooki *et al*. (2003) recorded *Rhabdochona hellichi*, *Bothriocephalus gowkongensis* and *Paradiplozoon homoion*, all reports from fishes captured in the Tajan and Zarem rivers of Mazandaran.

**Economic importance.** This species is said to taste even better than trout (Abdurakhmanov, 1962). It is caught by some anglers but is not commercially important (Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya, 2003).

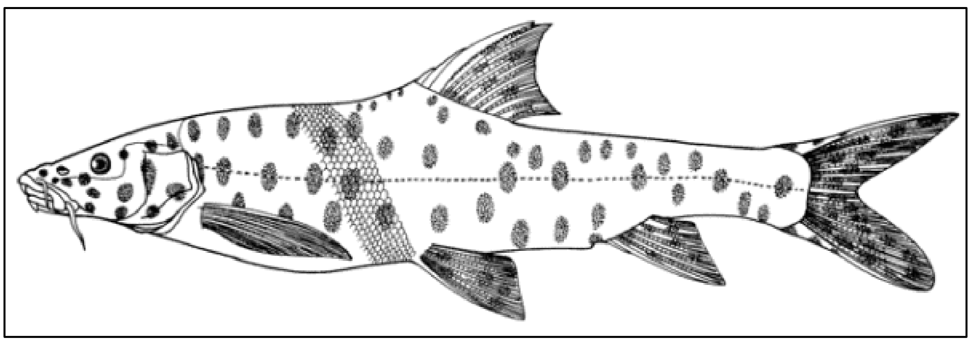
**Experimental studies.** None.

**Conservation.** Kiabi *et al*. (1999) considered this species to be near threatened in the south Caspian Sea basin according to IUCN criteria. Criteria included sport fishing, medium in numbers, habitat destruction, widespread range (75% of water bodies), present in other water bodies in Iran, and absent outside the Caspian Sea basin. Mostafavi (2007) listed it as near threatened in the Talar River, Mazandaran. Bogutskaya, Bănărescu and Almaça in Bănărescu and Bogutskaya (2003) reported that it is extremely rare in Azerbaijan. Endangered in Turkey (Fricke *et al*., 2007). Listed as of Least Concern by the IUCN (2015).

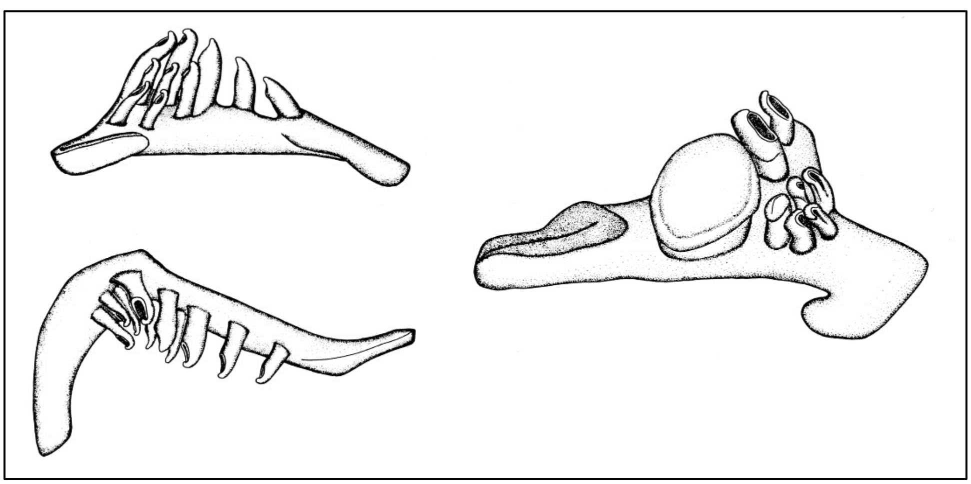
**Sources.** Iranian material:- CMNFI 1970-0525, 1, 49.3 mm standard length, Gilan, Sefid River near Mohsenabad (ca. 37º22'N, ca. 49º57'E); CMNFI 1970-0538, 5, 42.5-82.7 mm

standard length, Gilan, Qezel Owzan River above Manjil Dam (36º44'N, 49º24'E); CMNFI 1970-0545, 1, 43.3 mm standard length, Gilan, Sefid River (37º01'N, 49º38'E); CMNFI 1970-0589, 1, 110.0 mm standard length, Gilan, Sefid River opposite Kisom (37º12'N, 49º54'E); CMNFI 1979-0084, 2, 92.5-96.8 mm standard length, Mazandaran, Chalus River (no other locality data); CMNFI 1979-0456, 2, 44.1-50.2 mm standard length, Gilan, Shah River at Lowshan (36º37'30"N, 49º31'E); CMNFI 1979-0481, 1, 142.7 mm standard length, Golestan, stream 3 km west of Ghalahleekesh (37º18'30"N, 55º31'E); CMNFI 1980-0132, 1, 112.5 mm standard length, Gilan, Sefid River at Kisom (37º12'N, 49º54'E); CMNFI 1991-0158, 1, 81.1 mm standard length, Golestan, Madar Su (37º23'N, 55º47'E); CMNFI 1993-0136, 1, 109.9 mm standard length, Mazandaran, Sardab River (36º39'42"N, 51º22'36"E); CMNFI 2007-0086, 1, 182.2 mm standard length, Ardabil, Qareh Su basin near Nir (ca. 38º02'N, ca. 48º00'E).

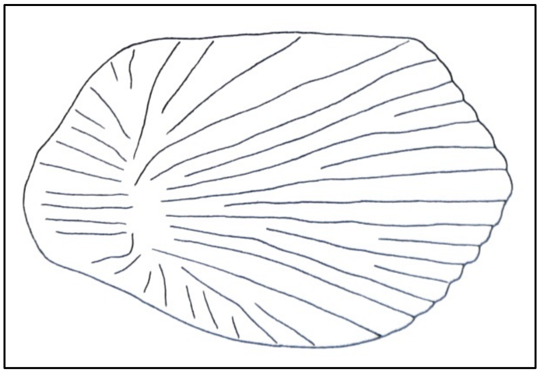
## ***Luciobarbus subquincunciatus***
(Günther, 1868)



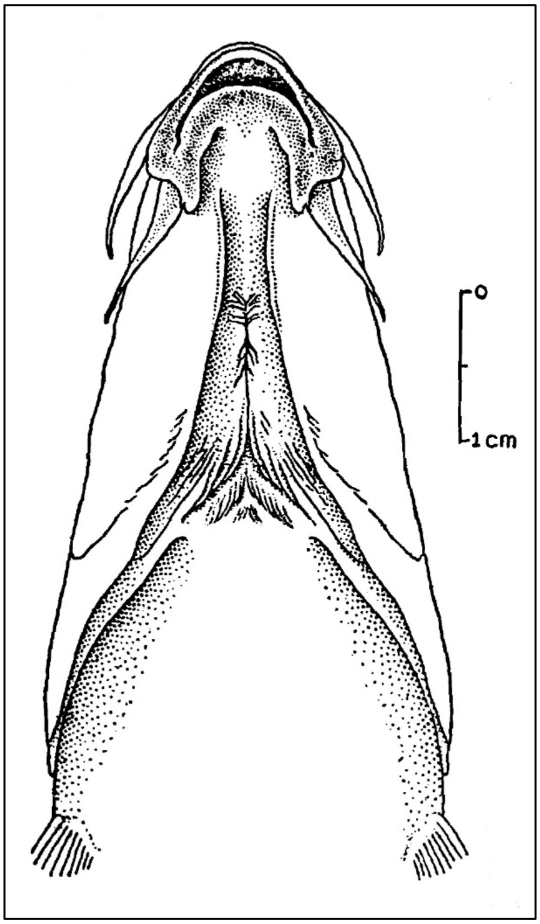
*Luciobarbus subquincunciatus*
Susan Laurie-Bourque @ Canadian Museum of Nature.



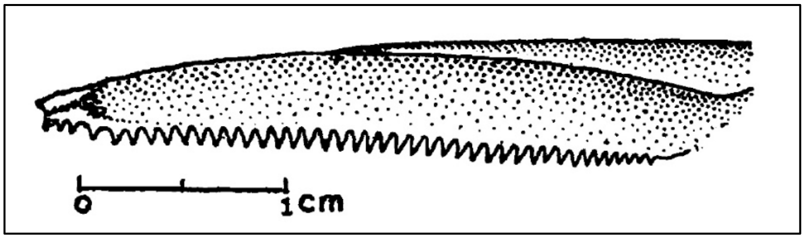
*Luciobarbus subquincunciatus*, pharyngeal teeth
(young on left, adult on right), Friedhelm Krupp.



*Luciobarbus subquincunciatus*,
scale, Freidhelm Krupp.



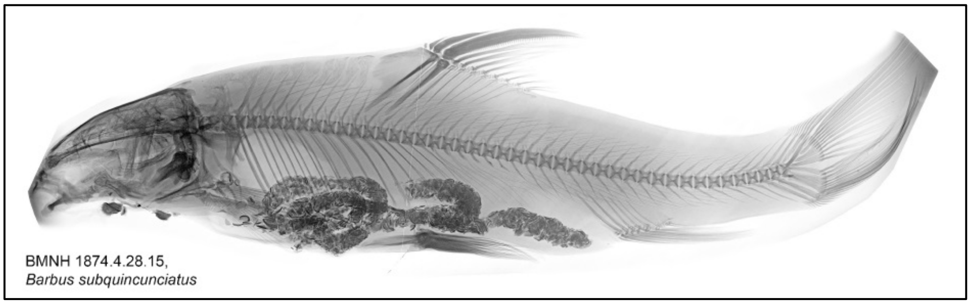

*Luciobarbus subquincunciatus*,
33.8 cm total length, ventral head,
Iraq, Baghdad, after Menon (1960).




*Luciobarbus subquincunciatus*, dorsal fin spine, as above.

*Luciobarbus subquincunciatus*, Khuzestan, Brian W. Coad.

*Luciobarbus subquincunciatus*, Iraq, Tigris River at Baghdad, FMNH 51260,
Brian W. Coad.




*Luciobarbus subquincunciatus*, BM(NH) 1874.4.28:15, 415.3 mm standard length, Iraq, Tigris River near Baghdad, Natural History Museum Data Portal (data.nhm.ac.uk), https://doi.org/10.5519/0002965.

**Common names.** Soleimani, soleymani or solimani (= Solomon, but why applied to fish unknown – see under *Mesopotamichthy sharpeyi*).

[Abou khazzama (from abu (meaning an animal having) and khizzama (meaning nose ring or an old-fashioned cannon with a hitching ring for a horse)), a'djzan, adzan, a'gan, agzan or ajzan (perhaps related to ijzan or cuckoo), nabish (or nabbash meaning to keep digging up, unearthing, referring to feeding behaviour (Mikaili and Shayegh, 2011)), all in Arabic; Leopar sazanı and Bıyıklı balık (in Turkish) and Komando balığı (local name in eastern Turkey) (Kaya *et al*., 2016; Çiçek *et al*., 2020); black spot barb, leopard barbel, Mesopotamian barb, Mesopotamian barbel, Solomon barbel].

**Systematics.** The type locality of this species is unknown. Günther (1859-1870) gave the following account:- "From the Collection of the East-India Company.- Although no record of the history of this specimen has been preserved, it is probable that it came from Mesopotamia, as other examples from this country are preserved in precisely the same manner". The type specimen is a "Skin, 15 inches long" (= 5.9 cm). The catalogue number is BM(NH) 1860.3.19:1469 (the catalogue year in the *Catalog of Fishes* is given as 1869 which, given the year of description (1868), seems more accurate than the label).

*Barbus subquincunciatus*, holotype, BM(NH) 1860.3.19:1469, Natural History Museum Data Portal (data.nhm.ac.uk), https://doi.org/10.5519/0002965.

Krupp (1985a) removed this species from *Bertinius* Fang, 1943 since the enlarged molariform pharyngeal teeth on which this genus was erected are due to convergence and are not evidence of monophyly. Howes (1987) placed this species in his *Barbus sensu stricto*.

**Key characters.** The numerous, large, dark spots arranged in an almost quincunx pattern are distinctive.

**Morphology.** The body is rounded and somewhat compressed, moderately deep to shallow. There is a predorsal ridge in some fish. The head profile is slightly convex with the dorsal profile in front of the dorsal fin gently rounded to quite convex. The snout is gently rounded to pointed. The caudal peduncle is compressed and moderately deep. The mouth is small, inferior and horseshoe-shaped, lips are very thick and fleshy, and the lower lip is thickened centrally like a median lobe but without a free posterior margin. Barbels are thick but quickly taper to the tip, the anterior one reaching between the nostrils and just beyond the anterior eye margin, and the posterior one to the anterior eye margin or beyond the posterior eye margin. The dorsal fin margin is concave and nearly perpendicular to the back. The last unbranched dorsal fin ray is very strong with strong denticles over three-quarters or more of its length. The depressed dorsal fin extends back to before or past the anal fin origin level. The dorsal fin origin is slightly in advance or over the origin of the pelvic fin. The anal fin is rounded to straight or slightly emarginate. The anal fin does not reach back to the procurrent caudal fin rays. The pelvic fin has a straight margin and extends back almost to the anus or well short. The pectoral fin is rounded to emarginate. The caudal fin is moderately forked with the tips rounded to pointed. The above is based in part after Almaça (1991) on a Euphrates River specimen.

Dorsal fin with 3-4 unbranched and 8 branched rays, anal fin with 3 unbranched and 5 branched rays. Pectoral fin branched rays 14-18 and pelvic fin branched rays 5-7. Lateral line scales 75-88. Scale shape is a horizontal oval with a rounded or very rounded protruding posterior margin, straight to very slightly rounded dorsal and ventral margins and an anterior margin with a very protruding centre indented above and below. Anterior scale corners are sharp to rounded. Scales have few radii on all fields, fine circuli and a focus slightly subcentral anterior. Total gill rakers are about 10-13, broad based and triangular in shape with highly tubercular distal or foliose margin. The longest raker reaches the one below when appressed. Pharyngeal teeth are 2,3,3,-3,3,2, occasionally 2,3,4-4,3,2, the usual number of teeth in the inner row in large specimens being 3 (Krupp, 1985a). The third inner row tooth is the biggest by far and is molariform. Juveniles have 5 inner row teeth (Krupp, 1985c). The gut has many anterior loops, the number increasing with size. Total vertebrae number 45-46 (in part after Howes (1987) and x-ray above).

Meristic values for an Iranian specimen are:- dorsal fin branched rays 8(1), anal fin branched rays 5(1), pectoral fin branched rays 14(1), pelvic fin branched rays 5(1), lateral line scales 83(1), total gill rakers 10(1), and pharyngeal teeth 2,3,4-4,3,2(1).

**Sexual dimorphism.** Unknown.

**Colour.** The whole body, head, fins, barbels, lips and even eyeball are covered with dark rounded or elongate spots about the same size as, or larger than, the eye. Some larger flank spots are 2-3 times the eye diameter. Spots on fins are elongated along the fin length. These spots are arranged in patterns similar to a quincunx, hence the species name. A quincunx comprises four spots, one at each corner of a square with the fifth spot in the middle of the square. Sometimes a spot runs into an adjacent one. Some spots below the lateral line may be elongate, three times longer than wide, and arranged vertically. Occasional fish lack spots on the mid-flank but are still distinctively spotted elsewhere. The overall colour is greenish, dark brown to brownish-yellow with the belly white or similar to the flank. The mid-dorsal fin may be orange and orange tints may appear at the caudal fin base. The pectoral and pelvic fins are dark red. The peritoneum is dark brown to black.

**Size.** Reaches 33.8 cm total length (Menon, 1960), 45.7 cm (Khalaf, 1961), 51.0 cm

standard length (Kaya *et al*., 2016) or 60.0 cm (Sauvage, 1884).

**Distribution.** This species is found in the Tigris-Euphrates basin including its Iranian portion in such rivers as the Absefidrag, Arvand, Gamasiab, Jarrahi, Javanrud, Kahnak, Karasu-Gamasiab-Seymarreh system (= Qareh Su-Gamasiab-Simareh) and Karun, and in the Gotvand Dam (Wossughi, 1978; Rainboth, 1981; Abdoli, 2000; Khamees *et al*., 2019; Jouladeh-Roudbar *et al*., 2020).

**Zoogeography.** Almaça (1991) believed that this species originated in Mesopotamia.

**Habitat.** This species is found in rivers, dams and marshes but habitat requirements are otherwise unknown.

**Age and growth.** Şen *et al*. (1992) examined nine fish in Keban Dam, Turkey and found age groups 3-7, growth rings best expressed in sectioned dorsal fin rays. The length-weight relationship was logw = - 5.78723 + 3.27533 logl and the mean $K_{(TL)}$ was 0.8234. The *b* value indicated the habitat was suitable for the species.

**Food.** The molariform pharyngeal teeth and evidence from gut contents showed this species is an obligate molluscivore (Krupp, 1985a). However, Hussain and Ali (2006) examined feeding relationships among fishes in the Hawr al Hammar and found this species to be an omnivore, 47.2% of the diet being algae and 28.9% detritus. Dietary overlap of 77% was found between this species and *Barbus* (= *Arabibarbus*) *grypus* but the availability of food resources offset possible competition. Al-Rudainy (2008) gave diet in Iraq as insects, as well as detritus and aquatic plants, but this may apply to younger fish**.**

**Reproduction.** Sexual maturity is attained at 3-4 years, 35 cm length and 500 g weight in Iraq. Spawning takes place in April and May with eggs deposited on rocks (Al-Rudainy, 2008).

**Parasites and predators.** None reported from Iran.

**Economic importance.** This species occasionally occurs in commercial catches in Khuzestan but is not a common food fish compared to other *Luciobarbus* and related species. It has been investigated for aquaculture in Khuzestan but fish are rare and so adults are caught and released.

**Experimental studies.** None.

**Conservation.** This species is now very rare in Iran. Reports of one fish taken in the Gamasiab River in 1991, four fish from the Karun River in 1995 and one fish from the Karun River at Ahvaz in 1997 were the only records for the 1990s (M. Ramin, pers. comm., 2000). The stock of this species in the Gamasiab River is severely reduced and during four years of collecting in western Iran, only one fish was caught (J. Valiallahi, www.modares.ac.ir, downloaded 4 July 2000; pers. comm., 2001; Valeolahy, 2000).

Syrian populations in the Euphrates River and parts of its tributaries are also in a parlous state (R. Beck, pers. comm., 2000). Smith *et al*. (2014) listed it as Critically Endangered, accidental harvesting being the principal threat coupled with its inability to live in reservoirs, unlike other large barbs (which conflicts with records above). Listed as Critically Endangered by the IUCN (2015) and perhaps on the brink of extinction. It is apparently very sensitive to pollution and may be strongly affected by dam construction (although Jouladeh-Roudbar *et al*. (2020), for example, recorded it from the Gotvand Dam). Freyhof *et al*. (2020) also listed commercial overfishing and water extraction as factors in its decline.

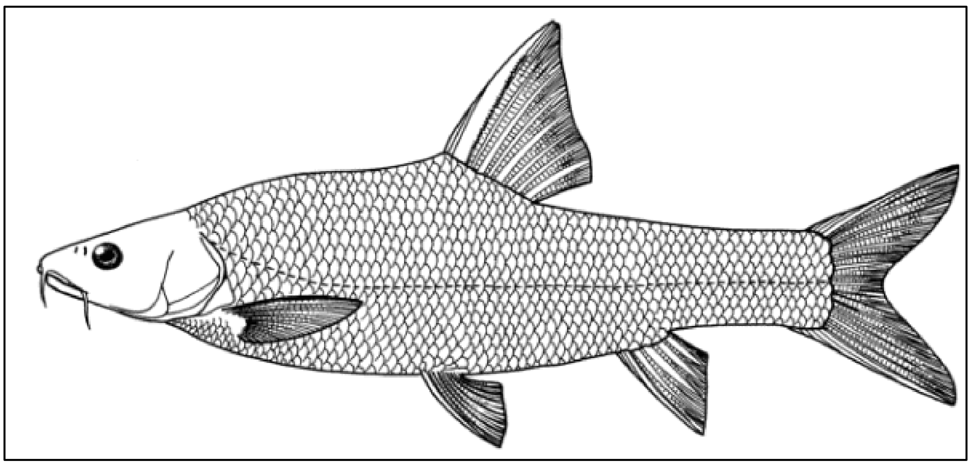
**Sources.** Type material:- *Barbus subquincunciatus* (BM(NH) 1869.3.19:1469).

Iranian material:- CMNFI 1993-0133, 187.0 mm standard length, Khuzestan, neighbourhood of Ahvaz (no other locality data); ZMH 2506, 1, 308.0 mm standard length,

Kermanshah, Karasu-Gamasiab-Seymarreh (= Qareh Su-Gamasiab-Simareh, no other locality data); FMNH 70794,1, no length data, Kermanshah, Javanarud near Kermanshah (no other locality data); and market specimens from Khuzestan.

Comparative material:- CMNFI 1980-1036, 1, 177.5 mm standard length, Turkey, Keban Dam on Murat Nehri near Elazig (38º41'N, 39º14'E); CMNFI 1986-0676, 1, 283.0 mm standard length, Turkey, Keban Dam on Murat Nehri (no other locality data); BM(NH) 1874.4.28:15, 1, 415.3 mm standard length, Iraq, Tigris River near Baghdad (33º21'N, 44º25'E); BM(NH) 1875.1.14:3-5, 3, 377.6-468.2 mm standard length, Iraq, Tigris River (no other locality data); BM(NH) 1974.2.22:1353, 1, 253.4 mm standard length, Iraq, Sirwan River, Diyala (no other locality data).

## ***Luciobarbus xanthopterus***
Heckel, 1843



*Luciobarbus xanthopterus*
Susan Laurie-Bourque @ Canadian Museum of Nature.

*Luciobarbus xanthopterus*, Khuzestan, S. A. Mortezavizadeh.

*Luciobarbus xanthopterus*, Khuzestan, Dez River (above),
Iraq, Tigris River near type locality, after Jouladeh-Roudbar *et al*. (2020).

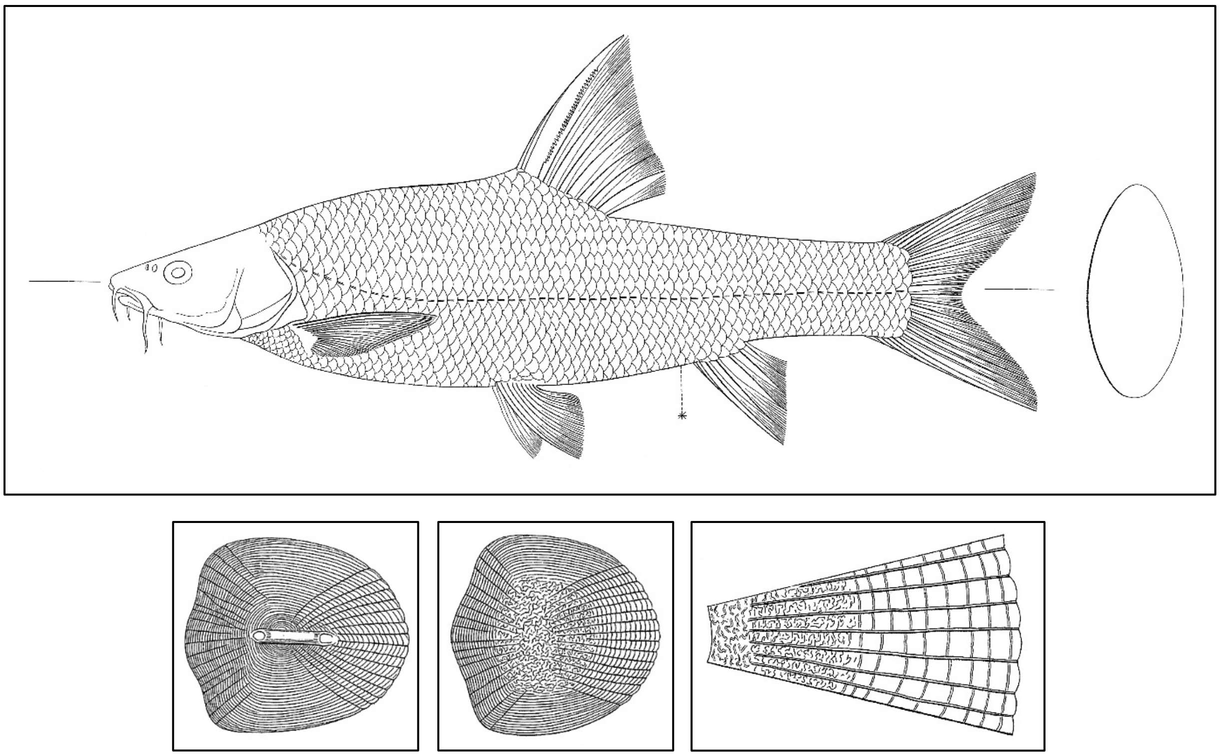
**Common names.** Gatan or gattan (see below), charsol.

[Gattan, ghattan, kattan, khattan (or kattan or qattan, perhaps from the Semitic root q-t-n meaning to be small, thin and frail, or more probably from q-t-t meaning to quarrel, discord), nobbash (or nabbash meaning to keep digging up, unearthing, referring to feeding behaviour (Mikaili and Shayegh, 2011); however Y. Keivany, pers. comm., 25 September 2018, suggested gattan is probably from the Arabic for thick or huge), or thekar, all in Arabic; Maya balığı in Turkish (Çiçek *et al*., 2020); yellowfin barbel].

**Systematics.** Howes (1987) placed this species in his *Barbus sensu stricto*. Almaça (1983, 1986) briefly reviewed the placement of this species in synonymy; most ichthyologists now regard it as a distinct species. *Luciobarbus xanthopterus* has been considered as a variant of *L. schejch* but differs in gill raker count (10-13 in *xanthopterus*, 21 in *schejch*) and main row pharyngeal tooth count (5 in *xanthopterus* and 4 in *schejch*) (Almaça, 1983). Heckel (1843b), however, gave the main row count for *xanthopterus* as 4. It has also been considered as a synonym of *esocinus* (*q.v.*) (Almaça, 1986). Jouladeh-Roudbar *et al*. (2020) stated that its validity needed to be confirmed by molecular markers.

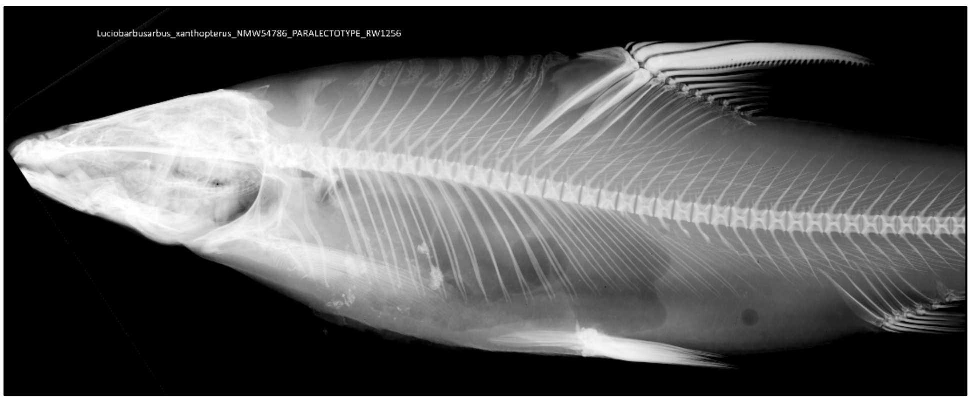
Fayazi *et al*. (2006) used mtDNA to study differentiation between populations of this species in the Jarrahi, Karkheh and Karun rivers in Iran. Diversity was low although the Karkheh and Karun fish grouped together, leading to the recommendation that fish from the Jarrahi should not be used to stock other river basins.

Almaça (1986) recorded syntypes of *Luciobarbus xanthopterus* from the type locality given by Heckel (1843b) “Tigris bei Mossul”, Iraq in the Naturhistorisches Museum Wien under NMW 54841 (10 specimens, one large fish at 216.5 mm standard length and nine smaller fish at 48.6-63.4 mm; one of these was noted as being listed as the lectotype in 1997 (presumably the largest), and the catalogue number was NMW 54841a) and NMW 54786 (one specimen, 292.8 mm, not listed as a type in 1997 but listed as such in the *Catalog of Fishes*, downloaded 6 June 2018). Material listed under NMW 1843 (presumably collection date rather than catalogue number) may also be syntypes. Eschmeyer *et al*. (1996) listed one dried syntype (paralectotype on photograph label) under NMW 91215. The catalogue in Vienna listed four fish in spirits and two fish stuffed.

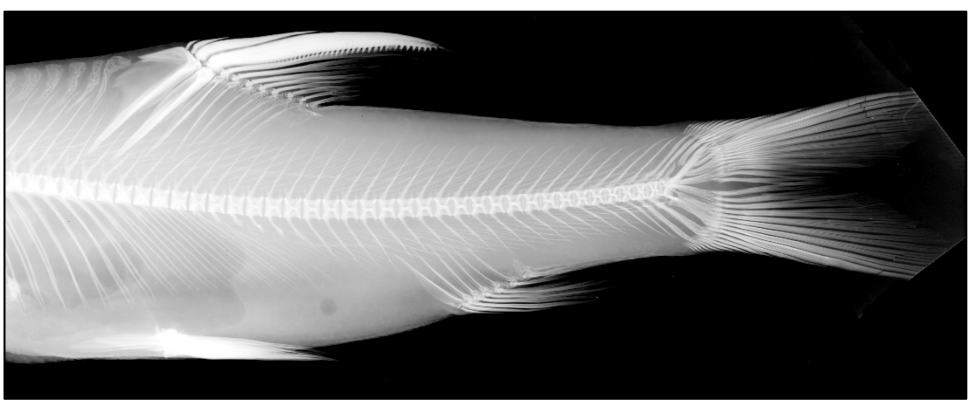


*Luciobarbus xanthopterus*,
body and cross-section, lateral line scale, flank scale from between the dorsal fin and lateral line (regenerated), and detail of flank scale, Naturhistorisches Museum, Wien, after J. J. Heckel.


*Luciobarbus xanthopterus*, paralectotype, NMW 54786, Naturhistorisches Museum Wien.



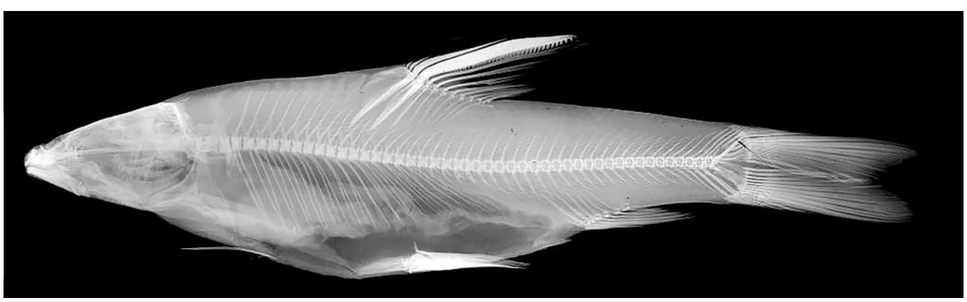

*Luciobarbus xanthopterus*, paralectotype anterior, NMW 54786,
Naturhistorisches Museum Wien.



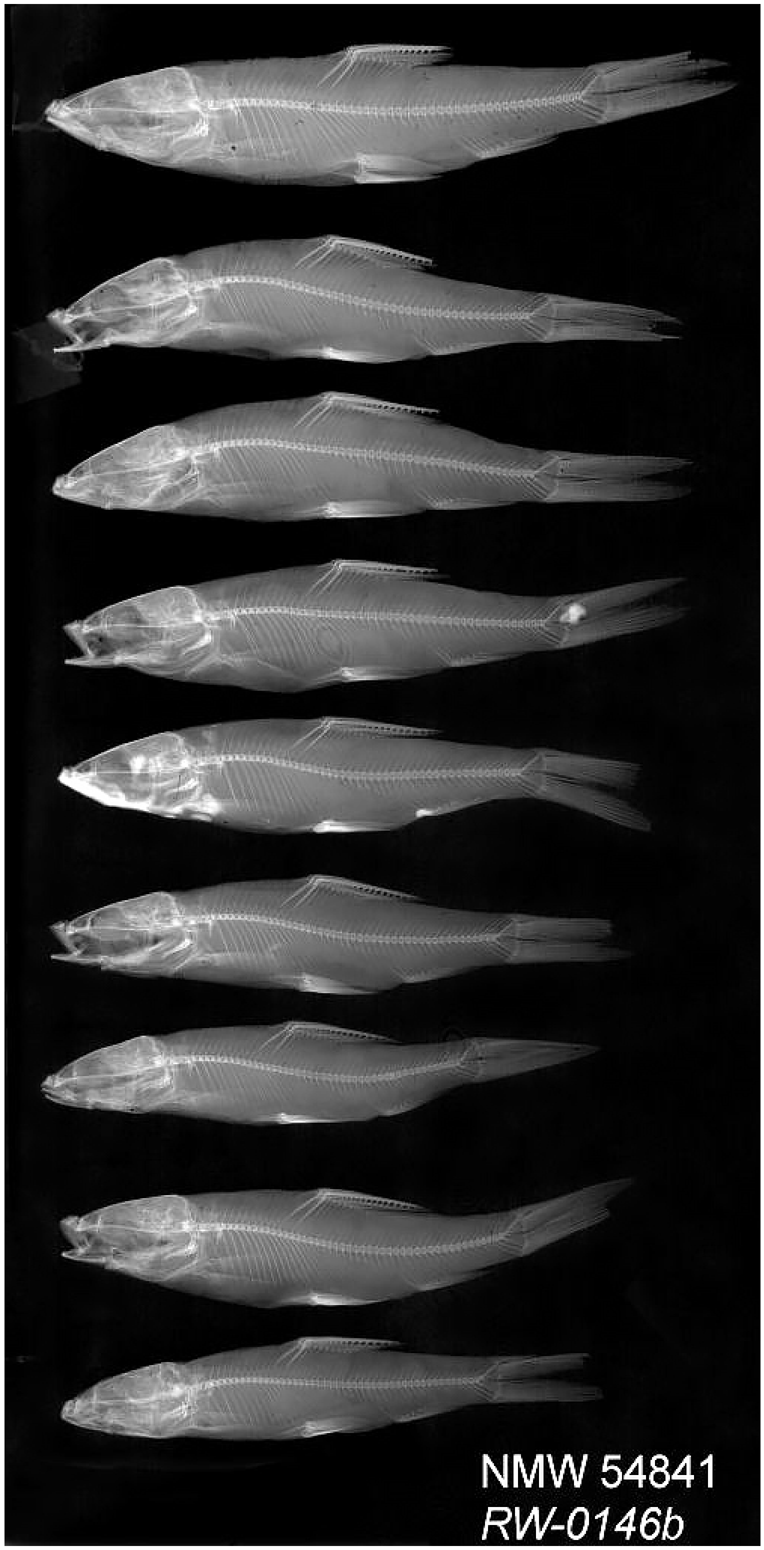
*Luciobarbus xanthopterus*, paralectotype posterior, NMW 54786,
Naturhistorisches Museum Wien.

*Luciobarbus xanthopterus*, syntype, NMW 54841, Naturhistorisches Museum Wien.

*Luciobarbus xanthopterus*, syntypes, NMW 54841, Naturhistorisches Museum Wien.



*Luciobarbus xanthopterus*, syntype, NMW 54841, Naturhistorisches Museum Wien.




*Luciobarbus xanthopterus*, syntypes, NMW 54841,
Naturhistorisches Museum Wien.

*Luciobarbus xanthopterus*, paralectotype, NMW 91215, Naturhistorisches Museum Wien.

Khaefi *et al*. (2017, 2018) reported on hybrids with *L. barbulus* in the Iranian Tigris River basin.

**Key characters.** This species is characterised by relatively small scales (55-69 in lateral line), a low total gill raker count (7-14), and a subterminal to terminal and oblique mouth. The elongate postorbital length is also seen in *Luciobarbus esocinus* but is more marked in the latter (7.2 times or less in standard length for *esocinus* compared to 7.7 or more times in *xanthopterus*).

**Morphology.** The body is compressed and moderately deep. The anterior dorsal profile is convex and falls rapidly to the snout tip. The caudal peduncle is short and moderately deep. The head profile is rectilinear, thinning forward of the nostrils, tapering to the snout tip. Head length is less than in *L. esocinus*, 5.0 in total length versus 3.9-4.1. The postorbital distance is relatively long although not as long as in *L. esocinus*, equal to or exceeding the distance from the snout to the posterior eye margin. The eyes are close to the upper profile and the mid-point of the eye is well anterior in the head. The mouth is terminal to slightly subterminal and shallowly oblique and extends back to the level of the rear nostril and almost to the eye. The mouth is moderate in size, inferior and an elongate u-shape in young fish and, as development progresses, becomes terminal in adults (Karaman, 1971; Almaça, 1984b). Lips are thin to moderately thick and the lower lip lacks a median lobe. The posterior part of the upper lip is thicker than the anterior part while the reverse is true for the lower lip. The lower lip is papillose and papillose tissue extends back as a continuous patch with clearly defined edges. Barbels are slender, the anterior one not reaching or just reaching the nostril level and the posterior one the anterior half of the eye or to the rear eye margin level. The dorsal fin margin is emarginate and almost perpendicular to the back. The last unbranched dorsal fin ray is very strong with strong denticles over three-quarters of its length. The depressed dorsal fin extends back to or past the anal fin origin level. The dorsal fin origin is slightly in front of, over or behind the origin of the pelvic fin. The caudal fin is quite deeply forked and has rounded tips. The anal fin is emarginate and does not reach back to the procurrent caudal fin rays. The pelvic fin is rounded and remote from the anus. The pectoral fin is rounded and extends back well short of the pelvic fin. The above in part is after Almaça (1986) based on 11 syntypes (NMW 54786 and NMW 54841).

Dorsal fin with 4 unbranched and 7-9, usually 8, branched rays, anal fin with 3 unbranched and 5 branched rays, pectoral fin branched rays 14-18, and pelvic fin branched rays 8-10. Lateral line scales 55-69. There is no distinct pelvic axillary scale. Scales have rounded dorsal, ventral and posterior margins and an anterior margin with a central

protuberance and indentations above and below. Circuli are fine and radii are found on the anterior and posterior fields and sometimes the lateral fields. The focus is subcentral anterior. Total gill rakers number 7-14, short and reaching the adjacent raker when appressed. Pharyngeal teeth are 2,3,5-5,3,2, strongly hooked, the fourth tooth of the inner row being the largest, and anterior teeth being rounded with a small flat or concave grinding surface below the tip. Qasim and Niazi (1975) gave a tooth formula of 4,3,2-2,3,4, i.e., 2,3,4-4,3,2 as did Heckel (1843b) and teeth were molariform. The gut has one anterior and two posterior loops in an elongate s-shape. Total vertebrae number 44 (Howes, 1987), 40-42 (Qasim and Niazi, 1975), or 42 (Wossughi, 1978), all presumably different counting methods. Five syntypes of *L. xanthopterus*, NMW 54841, have 48 total vertebrae and the paralectotype, NMW 54786, has 48 total vertebrae. Jawad *et al*. (2015) documented a case of vertebral coalescence in fish from Al-Huwaizah Marsh in Iraq, the fish having 11 thoracic and 11 caudal vertebrae.

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(2), anal fin branched rays 5(2), pectoral fin branched rays 18(2), pelvic fin branched rays 8(2), lateral line scales 57(1) or 68(1), total gill rakers 7(1) or 10(1), pharyngeal teeth 2,3,5-5,3,2(2).

**Sexual dimorphism.** Unknown.

**Colour.** The back and flanks bear small, scattered spots. The back is golden brownish to bluish-grey, the flanks are silvery to silvery-yellow, and the belly is white. The scales are outlined by melanophores. The overall colour from a marsh habitat is darker than from a riverine habitat, the pigment outlining scales being thicker for example, especially at the scale base. The iris is red in marsh specimens, white to yellowish elsewhere (M. Al-Mukhtar, pers. comm., 1995). All fins are lemon-yellow to orange or red with some darker melanophores. The dorsal fin unbranched rays and the uppermost caudal fin rays are black.

Two small specimens from Iran have irregular spots and blotches on the flank. The peritoneum is silvery with melanophores developed dorsally.

**Size.** Al-Hassan *et al*. (1986) reported a specimen 1.5 m total length and 8.6 kg from the Al Khasib area in the Shatt al Arab, Iraq. Bartel *et al*. (1986) gave a maximum weight of 30.0 kg for Iraqi lakes, if correctly identified. A fish presumed to be this species caught in Lost Lake, a palace pond in Baghdad, weighed 15 pounds (6.8 kg) and was 34 inches long (0.86 m) (http://members.cox.net/flybox/FishingUpdate.htm, downloaded 9 January 2006).

**Distribution.** This species is found in the Tigris-Euphrates basin including its Iranian portion such as the Alvand, Arvand, Dez, Gamasiab, Hofel, lower Jarrahi, Kahnak, Karkheh, lower Karun, Marun, Qareh Su and Shate-Neisan rivers, the Hawr al Azim and Shadegan wetlands and the Marun Dam (Abdoli, 2000; Fayazi *et al*., 2006; Mohammadi *et al*., 2012; Darabi *et al*., 2015; Khaefi *et al*., 2018; Khamees *et al*., 2019).

**Zoogeography.** Almaça (1984b, 1991) considered that the origin of this species lies with a group that migrated southwards in the late Pliocene from the Dacian Lake of the Sarmatian Sea and speciated in Mesopotamia. See also under the genus.

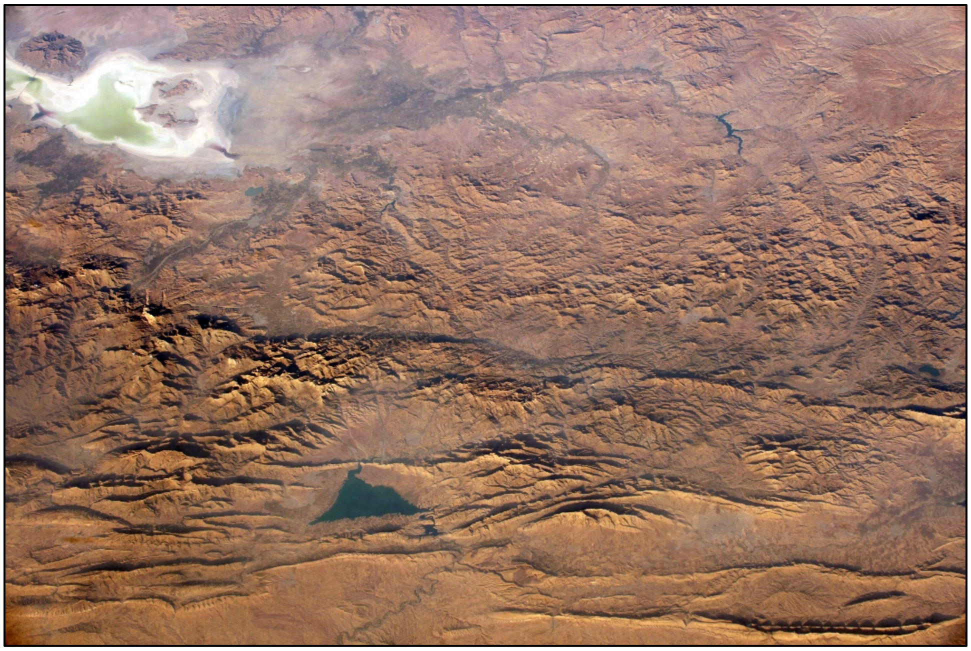
**Habitat.** This species is found in rivers, lakes, dams, large ponds, marshes and springs. In Khuzestan, this species is most abundant in the Karkheh River in March and in the Hawr al Azim in December, migrating from the wetland to the river in spring. Younger fish are more abundant in the wetland and older fish in the river (*Iranian Fisheries Research Organization Newsletter*, 22:3, 2000; Eskandari *et al*., 2000). Another study showed this species to be most abundant in the Karkheh River in December, with a migration from wetlands in spring to the main river (*Tehran Times*, 1 October 2000).

van den Eelaart (1954) and Al-Hamed (1966b, 1972) described the habitat for this

species in the Tigris River, Iraq as distributed in the deep, open waters of lakes and vegetated marshes and to a lesser extent in the river and its tributaries. Mature fish moved upstream to the spawning grounds in February-March and spent fish descended to their original habitat in lakes and marshes. In summer, beginning in June, under low water level conditions and high temperatures, the smaller fish remained in the deepest depressions of lakes but the large fish (3.0 kg or more) migrated up rivers and tributaries in search of cooler water, returning in September and October when temperatures fell to fatten over winter. In cold winters they descended to the deeper water layers and remained on the bottom without feeding (van den Eelaart, 1954).

**Age and growth.** In the Karkheh River, male fish matured at 15.1-20.0 cm (one-year-old) and females at 50.1-55.0 cm (three-year-old). The male:female sex ratio was 1:1.31 but this was not significantly different from 1:1 (Eskandari *et al*., 2000).

Life span is at least 11 years, based on Iraqi fish (Al-Ahmed, 1966a). Al-Hamed (1966b, 1972) working on Tigris River fishes in Iraq found males to mature at about 43 cm and females at about 48 cm, maturity being attained in the fourth year of life and spawning occurring at the beginning of the fifth. Some fish matured at age group 3 and some as late as age group 5. Males outnumbered females on the spawning grounds, comprising 62% of the population. Tigris River and Tharthar Reservoir fish in Iraq had 7 age groups with growth good in the first 3 years and slower thereafter (Ali, 1979). In the Al Qadisiyah Dam on the Iraqi Euphrates, fish 215-420 mm in total length had an age range of 3-10 years, a length-weight relationship of log W = -5.01 + 3 log L, and a von Bertalanffy equation of $L_t = 120(1-e^{-0.015(t-1.27)})$ (Abulhani and Al-Rudainy, 2000). Growth in the Dukan and Derbendikhan dams in northeastern Iraq was slower than in waters of central Iraq (Ciepielewski *et al*., 2001) although Atallah (1978) reported fry in Lake Tharthar reached 11 cm total length in the first year, only slightly faster than in northern Iraqi basins. The oldest fish caught was 7 years old and ca. 50 cm total length in the Dukan Dam and 5 years and ca. 40 cm in the Derbendikhan Dam. The condition coefficient was 1.4 in Dukan and 1.56 in Derbendikhan, indicating condition was good. Ciepielewski *et al*. (2001) noted that although Daoud (1978) reported this species grew to 20.5 total length in the first year, and then 2-3 cm annually, in Dukan Dam this most probably resulted from incorrect placement of the first-year ring on the fish scales used in ageing.



Dukan Dam in Iraq with Lake Urmia top left
(ISS053-E-127206 - View of Iran, CC0, tone and colour adjusted, NASA).

Epler *et al*. (2001) found the oldest age groups to be $5^+$, $7^+$ and $8^+$ in lakes Habbaniyah, Razzazah and Tharthar respectively. The mean condition factor was 0.98, 1.01 and 1.17 in lakes Habbaniyah, Tharthar and Razzazah respectively. Syzpuła *et al*. (2001), studying age and growth in the lakes Habbaniyah, Tharthar and Razzazah in 1981 and 1982, found this species grew fastest in Lake Tharthar. The von Bertalanffy parameters were for Lake Tharthar $L_\infty$ (cm) = 109.0, K = 0.1233, $t_0$ = -0.3598, $W_\infty$ (g) = 13,106 and n = 2.8635, for Lake Razzazah these values were 122.4, 0.0926, -0.1609, 22,371 and 2.9598, and for Lake Habbaniyah 149.9, 0.0545, -1.0, 30,604 and 2.9849 respectively. These indicated rather uniform growth rates, as $L_\infty$ was relatively high and K very low. Results were more reliable than earlier studies by Al-Hamed (1966a) which used inappropriate methods. Annual survival in Lake Tharthar for fish 1.5-3.8 years was 58.8% and for Lake Habbaniyah for fish aged 2.0-4.3 years was 41.9% (Szczerbowski *et al*., 2001). Productivity was low, based on chemical and limnological studies, especially in Lake Tharthar, limiting fish production. Al-Jubouri (2019) examined 516 fish, total length 12-60 cm, from the Al-Diwaniyah River, Iraq and found this species comprised 5.62% of the fish assemblage, $W = 0.008L^{3.0933}$ allometric growth, the sex ratio differed significantly from 1:1 in favour of females, mean values of relative condition factor for small fish, males and females were 0.97, 0.86 and 0.92, respectively, seven (*sic*, see below) age groups were recognized with lengths 15.3, 26.3, 35.9, 42.8, 49.0 and 57.1 cm, length group 38 cm dominated, and von Bertalanffy growth constants were $L_\infty$ = 75 cm, K = 0.228 and $t_o$ = -0.012. The growth performance index (Φ) was 3.01. The total (Z), natural (M) and fishing (F) mortality rates were assessed by applying the length cohort analysis and were 1.6854, 0.241 and 1.444, respectively. The exploitation rate (E) estimate was 0.586, exceeding the optimal level of exploitation (E = 0.5), so this fish stock was overexploited. The following report was presumably based, at least in part, on this thesis. Mohamed and Al-Jubouri (2020a) examined 682 fish from the Al-Diwaniya River, Iraq and found the length range was 12.0 to 60.2 cm total length, $W = 0.008L^{3.093}$, positive allometric growth, the highest relative condition factor

was in April and the lowest in May, seven ages were identified and their mean lengths were 15.3, 26.3, 35.9, 42.8, 49.0, 54.7 and 57.1 cm, respectively, the von Bertalanffy growth model was $L_t = 73\ [1-e^{-0.228\ (t-0.012)}]$, the overall male:female ratio was1:1.57, and length at first maturity was 36 cm for males and 38 cm for females.

In Keban Dam, Turkey, age determination was best made on sectioned dorsal fin rays (of scales, otoliths, vertebrae and opercula) and up to 9 age groups were detected (Duman and Şen, 1995).

**Food.** In Khuzestan it was omnivorous, feeding mainly on insects and vegetation, but also taking secondarily shrimps, snails and ostracods (*Iranian Fisheries Research Organization Newsletter*, 22:3, 2000; Eskandari *et al*., 2003). In the Karkheh River, food was insects and vegetation mainly, with shrimps, gastropods and ostracods secondary food choices (*Tehran Times*, 1 October 2000). The intestine fullness was greater in fish in the Hawr al Azim, less in the Karkheh River, which latter was used mainly for spawning (Eskandari *et al*., 2003).

Ali (1979) for Iraqi waters gave insects and plankton as the principle foods and Al-Hassan *et al*. (1986) reported isopods and molluscs. Al-Hamed (1965) and Al-Shamma'a *et al*. (1999) considered this species to be an omnivore, consuming filamentous algae, detritus, frogs, molluscs, crustaceans, insect larvae and fishes and even planktonic organisms. Organic matter was obtained in periods of food shortage by engulfing mud from the pond bottom. van den Eelaart (1954) reported food to be plants, epiphytes and plankton. In cold winters, they took no food. Ciepielewski *et al*. (2001) found a small sample of mature fish caught in spring was feeding on plants and seeds of terrestrial origin, detritus and, less commonly, insects. The detritus component was much higher in summer as were chironomids; fish were also eaten. Hussein *et al*. (1993) studied the diet of this species in the Garma Marshes of Iraq and found molluscs to rank first in both winter and summer, with amphipods second. Other food groups were seeds and aquatic plants, insects, oligochaetes and fishes. Selectivity of diet items depended on fish size and availability. Molluscs such as *Corbicula* spp. were of particular importance, probably because of their large flesh content compared to other foods coupled with a benthic life and colourful appearance making them easy to capture. Epler *et al*. (2001) found the diet in Lake Tharthar to be dominated by plants (37.8%) and molluscs (37.6%) followed by fishes at 10.6% of the diet. In Lake Habbaniyah plants dominated (39.5%) followed by tendipedids (30.5%), detritus (11.5%), oligochaetes (7.6%) and fish (6.6%). Plants were important throughout the year with fish between March and July. Dietary coincidence was high in Lake Habbaniyah, 48.6% with himri (*Carasobarbus luteus*). A marked overlap in diet was noted with the exotics common carp (*Cyprinus carpio*) and the stinging catfish *Heteropneustes fossilis* (Hussein, 2000). Al-Rudainy *et al*. (2004) examined specimens from a man-made lake west of Baghdad and found food to be aquatic plants, insects and their larvae, algae, diatoms, detritus, zooplankton, molluscs and fish, indicating an omnivorous diet with the main food being aquatic plants. Feeding was highest in summer months. Feeding in the Hawr al Hammar was related to temperature, the peak intensities being June and the minimum in January with peak activity in June and minimum in February. Feeding occurred year-round and smaller fish (<20.0 cm) had highest feeding activity in spring while adults had this in summer (Hussein *et al*., 2000). Hussain and Ali (2006) examined feeding relationships among fishes in the Hawr al Hammar and found this species to be a carnivore (in their definition system), 23.4% of the diet being detritus, 26.9% crustaceans, 16.6% insects and 26.3% molluscs. Dietary overlap of 84% was found between this species and *Cyprinus carpio* but the availability of food resources offset possible competition. In another study of the recovering Hawr al Hammar, diet was

50.0% insects, 20.0% algae, 15.0% snails and 10.0% diatoms (Hussain *et al*., 2006). Food in Habbaniyah Lake varied seasonally in its composition with dietary items being molluscs and insects and their larvae (Al-Shamma'a, Mashhadany, Nasser and Alasha'ab, pers. comm., 19 October 2008). Al-Shamma'a *et al*. (2009) found this species to be omnivorous in Hemrin Dam on the Diyala River (61.3% animal material, with insects and their larvae ranking first). Ali (1979) for Iraqi waters gave insects and plankton as the principle foods. Al-Shamma'a *et al*. (2009) found fish from Lake Habbaniyah to feed mostly on animal materials (76.25%) including molluscs and insects and their larvae. Feeding was most active in spring but high feeding intensities were also observed in autumn. Al-Jubouri (2019) and Mohamed and Al-Jubouri (2020a) found fish from the Al-Diwaniya River, Iraq had significant correlations between water temperature and both feeding activity and intensity of the fish. The species was omnivorous and fed mainly on aquatic insects (37.0%), macrophytes (20.0%), detritus (20.0%), snails (14.0%), diatoms (9.0%) and crustaceans (no figure given).

**Reproduction.** In Khuzestan, spawning fish were 63.7-80.0 cm total length with a relative fecundity of 18.9-142.5 eggs/g body weight and a minimum and maximum absolute fecundity of 136,924 and 549,211 eggs (*Iranian Fisheries Research Organization Newsletter*, 22:3, 2000; Eskandari *et al*., 2003). In the Karkheh River, spawning took place at surface water temperatures of 25.5-28.65°C in turbid water after a spring migration from wetlands into the river (*Tehran Times*, 1 October 2000; Eskandari *et al*., 2000). Spawning occurred annually in May and June in the Karkheh River and maximum egg diameter was 2.25 mm (Eskandari *et al*., 2000).

van den Eelaart (1954) and Al-Hamed (1966b, 1972) studied the reproduction of this species in Iraq. Eggs were deposited on fine gravels overlying a layer of coarse sand in shallow, wide holes excavated by the fish. Water depth varied from 30 to 150 cm. Egg diameter was 1.0 mm and fecundity up to 340,000 grey eggs. Al-Hassan *et al*. (1986) recorded up to 350,000 eggs for their large fish from the Shatt-al-Arab. The spawning season on the Tigris River between Beled and Tigrit was April and May. Fish appeared on the spawning grounds in schools just before dark and remained there until shortly before midnight, making loud noises by splashing, jumping and chasing. Jubouri (2019) and Mohamed and Al-Jubouri (2020a) found fish from the Al-Diwaniya River, Iraq had the highest gonadosomatic index for females and males (7.79 and 4.24 respectively) in March indicating spawning activity starting after this month.

**Parasites and predators.** Bykhovski (1949) reported a new species of monogenetic trematode, *Dactylogyrus inutilis*, from this species in the Karkheh River, Iran. Ebrahimzadeh and Nabawi (1975) listed Anisakidae from fish in the Karun River. Moghainemi and Abbasi (1992) recorded a wide range of parasites in the Hawr al Azim in Khuzestan. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Argulus* sp., *Ergasilus* sp. and *Lamproglena compacta* on this species.

**Economic importance.** This species appeared regularly in the markets of Ahvaz and Wossughi (1978) stated it was of great economic importance. Sharma (1980) reported that it was the third most important fish species at Basrah, Iraq fish market, accounting for 510,503 kg for the period from October 1975 to June 1977. Petr (1987) reported the annual catch for 1976 in Iraq was 2,543 t.

Anglers in Iraq caught this fish which will reject any bait showing resistance, requiring a fast strike at the first indication that the fish has taken the bait. van den Eelaart (1954) gave the fishing season for this species in Iraq as February-May (peaking in April) and June-October

(peaking in July) in rivers, and February-April (peaking in March) and May-November (peaking in June-July) for lakes and marshes. Ali (1980) recommended a mesh size of 56 mm for the fishery based on an average length coefficient of 0.13.

**Experimental studies.** Askary Sary and Mohammadi (2011a) and Askary Sary *et al*. (2011a) found fish from the downstream Dez and Karun rivers were highly contaminated with such heavy metals as cadmium, lead, mercury and nickel, varying between tissues and the two rivers, but exceeding acceptable levels. Mohammadi *et al*. (2012) found heavy metal (cadmium, lead, mercury, nickel) concentrations were higher in fish from the Karun River than those from the Dez River, the levels varied with the tissues examined, and accumulation in both rivers was higher than the World Health Organization standard. Askary Sary and Mohammadi (2012a) found high levels of mercury in the liver of this fish in Khuzestan. Askary Sary and Mohammadi (2012b) found lead bioaccumulation in liver was 2.8 mg/kg wet weight in fish from the Karkheh River, more than that found in *Arabibarbus grypus*. Tabandeh *et al*. (2014) and Mohammadiyan *et al*. (2019) examined tissue distribution and activity of rhodanese, a mitochondrial enzyme that detoxifies cyanide, in fish from the Karun River. This data could then be used to assess severity of cyanide contamination of water or fishes. Tabandeh *et al*. (2014) found mercaptopyruvate sulphur transferase, a cyanide-detoxifying enzyme, in tissues of this species. Abdi and Alishahi (2014) showed that the pesticide diazinon was toxic to this species and toxicity increased with pesticide concentration. Bahrami *et al*. (2018) compared the acute toxicity of two herbicides, paraquat and 2,4-dichlorophenoxy acetic acid, finding the $LC_{50}$ 96 h was 8.7 mg/l and 37.8 mg/l respectively. Javaheri Baboli *et al*. (2019) found saturated and monounsaturated fatty acid composition in muscle was significantly influenced by seasons while polyunsaturated and mega3 fatty acids were not. Velayatzadeh and Askary Sary (2020) found the health risk of mercury in consumption of this species in southwest Iran was over one for both adults and children and so it was advisable to pay more attention to the consumption of this fish.

Zadeh *et al*. (2009) investigated the optimal dietary carbohydrate to lipid ratio for fingerlings of this species. Khosravizadeh *et al*. (2011) studied the effects of digestible energy levels on growth performance and whole body composition, determining that 3 kcal $g^{-1}$ digestible energy was preferable for fingerlings.

Ghoreishvandi *et al*. (2021) studied post-mortem chemical, physical, microbial and sensorial changes during ice storage and found the use of ice was not appropriate over the long term.

This species has been studied for pond culture in Khuzestan where over 95% of young survived, using hormones to stimulate reproduction (*Iranian Fisheries Research Organization Newsletter*, 28:3, 2001). Mortezavizadeh *et al*. (2009) induced reproduction in this species with common carp pituitary extract. Sperm production was increased, 86% of females responded positively, 480 eggs/g were produced, and mean survival rate was 77.95%. Propagation was best at the beginning of March at 19.0-24.5°C. Mabudi *et al*. (2013) showed that the integrated effect of injecting 7 μg of the hormone $LHRHA_2$ and 4 mg of pituitary extract gave the highest weight of extracted eggs, spawning success, fertilisation success, hatching rate and larval survival on fish studied for artificial propagation in the Dasht-e Azadegan Fish Culture Farm. Mortezavizadeh *et al*. (2011) investigated the best propagation techniques for this species in Khuzestan, attaining a spawning success of 87% in the broodstock, and releasing 660,000 larvae to earthen culture ponds. Karami-Motlagh *et al*. (2013) gave details on sperm morphology and chemistry, necessary for cryopreservation in brood stocks. Tabibi *et al*. (2017)

studied the use of activating solutions on sperm activity and fertilisation capability in comparison with grass carp. The highest values resulted from an a2 activating solution combined with NaCl and Tris-Hcl in both species, around seven times in sperm activity and around 20% in fertilisation.

**Conservation.** Several hundred thousand juveniles have been introduced into the Hawr al Azim in Khuzestan in order to restock and protect this resource. The fish were artificially bred from breeders using hormone treatment (*Iranian Fisheries Research Organization Newsletter*, 39:3, 2004; Network of Aquaculture Centres in Asia, downloaded 11 January 2007). Endangered in Turkey (Fricke *et al*., 2007). Smith *et al*. (2014) listed it as Vulnerable, overfishing being the principal threat. Listed as Vulnerable by the IUCN (2015) through dam construction, water abstraction, marsh drainage, pollution and overfishing. Widespread dam construction has blocked access to many spawning sites (Freyhof *et al*., 2020).

**Sources.** Type material:- *Luciobarbus xanthopterus* (NMW 54786 and 54841).

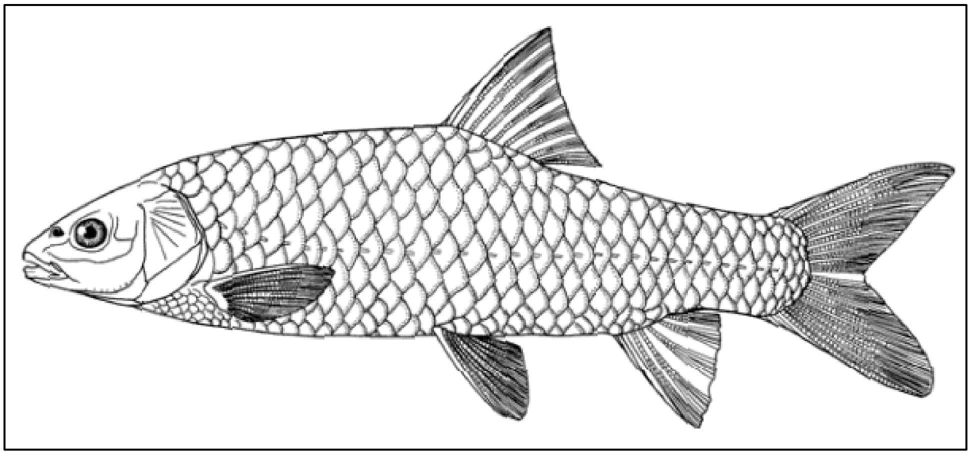
Iranian material:- CMNFI 2008-0117, 2, 93.7-112.8 mm standard length, Kermanshah, Sarab-e Yavari (34º28'N, 46º56'E); ZMH 4071, 1, 151.6 mm standard length, Kermanshah, Qareh Su at Kermanshah (ca. 34º19'N, ca. 47º08'E).

Comparative material:- BM(NH) 1893.6.23:25, 1, 198.0 mm standard length, Iraq, Al Faw (29º58'N, 48º29'E).

## Genus *Mesopotamichthys*
Karaman, 1971

Much of the past literature on this genus appeared under *Barbus* (*q.v.*). The genus contains a single species and the characters of the species are those of the genus. Borkenhagen (2017a, 2017b) characterised the genus by absence of barbels, pharyngeal teeth intermediate between spoon-shaped and shovel-shaped and numbering 2,3,5-5,3,2, lips fleshy and developed, broad orbital bones but a short lachrymal bone, sensory canals on the head similar to members of the genus *Tor*, dorsal fin branched rays 8 with the last unbranched ray moderately ossified and smooth, anal fin branched rays 5, relatively large scales with numerous parallel or convergent radii, and a black peritoneum.

### *Mesopotamichthys sharpeyi*
(Günther, 1874)



*Mesopotamichthys sharpeyi*
Susan Laurie-Bourque @ Canadian Museum of Nature.

*Mesopotamichthys sharpeyi*, Iran, Reza Salighehzadeh.

**Common names.** Benni, benny, beni, binni, bini, binny (meaning possibly nose, but probably from the Arabic brown), soleimani or solimani (= Solomon, but why applied to fish unknown. There is the biblical tale of the demon Asmodeus imprisoned by Solomon and when released throws Solomon miles away from Jerusalem, and his magic ring into the ocean, where it was eaten by a fish. Solomon goes fishing, finds the ring, and vanquishes the demon).

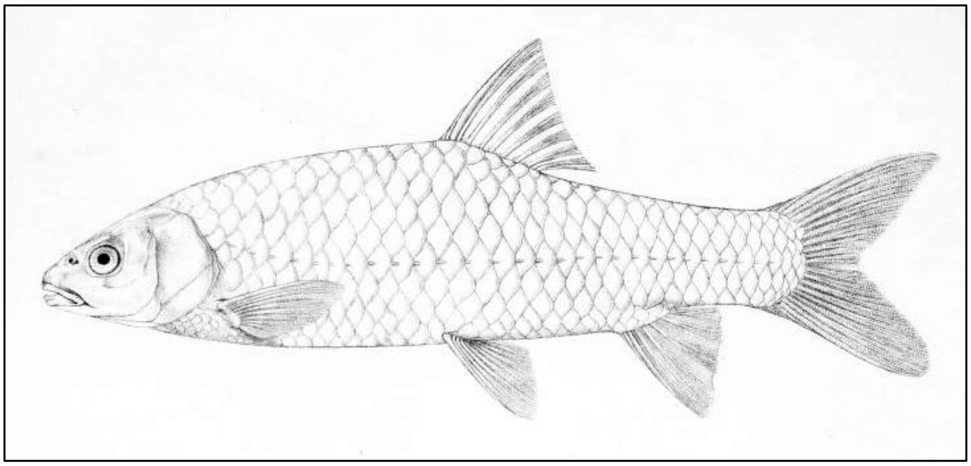
[Binni, bunni, bunnei, bunia; aradah at Baghdad according to Günther (1874) but this may be an error for *Acanthobrama marmid*, all in Arabic; Mesopotamian barb]. Nissan and Zuckermann (2015) noted that bunni is also the family name of an Iraqi ichthyologist (see Banister and Bunni (1980)), perhaps an example of nominative determinism. They also comment on the etymology of the Aramaic name binita for a fish in the Babylonian Talmud.

**Systematics.** Howes (1987) placed this species outside the genus *Barbus sensu stricto* as defined by him because it has the non-elongate lachrymal bone with a sensory canal running along the antero-dorsal border, a derived condition. Karaman (1971) erected a new genus for this species, *Mesopotamichthys*, which was not accepted by Krupp (1985c). However, Bănărescu (1997), Ekmekçi and Banarescu (1998) and Borkenhagen (2017a, 2017b) recognised this genus as valid.

*Barbus faoensis* Günther, 1896 described from "Fao (Persian Gulf)", Iraq is a synonym; Karaman (1971) retained it as the subspecies of the lower part of the Tigris-Euphrates basin with the type subspecies in the upper part of the Tigris River basin. This distinction has not been re-examined and a single taxon is recognised here.

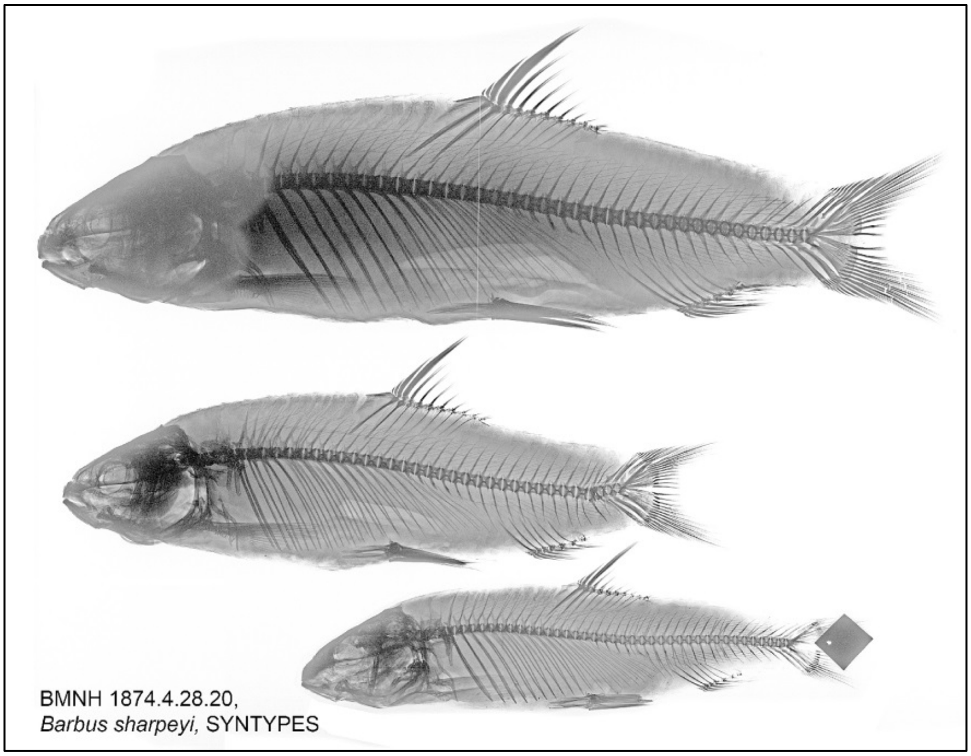
*Barbus sharpeyi* was described from "Baghdad". The three syntypes are in the Natural History Museum, London (BM(NH) 1874.4.28:20 labelled "R. Tigris nr. Baghdad. Sharpey",

well sealed in its jar and not measured accurately, and BM(NH) 1874.4.28:27 and BM(NH) 1875.1.14:16 labelled "R. Tigris. Sharpey" and measuring 147.6-178.0 mm standard length).



*Barbus sharpeyi*, syntype, after Günther (1874).

*Barbus sharpeyi*, syntype, BM(NH) 1875.1.14:16, Iraq, Tigris River,
Natural History Museum Data Portal (data.nhm.ac.uk), https://doi.org/10.5519/0002965.




*Barbus sharpeyi*, syntypes, BM(NH) 1874.4.28:20, Iraq, Tigris River near Baghdad, Natural History Museum Data Portal (data.nhm.ac.uk), https://doi.org/10.5519/0002965.

The large holotype of *Barbus faoensis* is also there, strongly sealed in its jar, labelled "Persian Gulf. Kurrachee Museum" (BM(NH) 1888.5.17:4).

Al-Mukhtar and Al-Hassan (1999) described a hybrid of this species and *Carassius auratus* from Al-Hayei (= Al Ha'i), a seasonal lake between the Karkheh and Dez rivers in Khuzestan.

Darabi *et al*. (2014) examined the phylogenetic relationships of fish from localities in Khuzestan, finding most genetic variance was within populations, a gene flow occurred between Karun and Jarrahi River fish, and concluded that the transfer and stocking between the Jarrahi and other rivers should be avoided to maintain genetic diversity.

**Key characters.** The absence of barbels, the last dorsal fin unbranched ray moderately ossified but lacking teeth, and the low scale count are characteristic.

**Morphology.** The body is compressed and moderately deep. It is deepest at or in front of the dorsal fin. Some fish are slenderer than others. The predorsal profile is slightly convex to the occiput and then is flat to the snout. The caudal peduncle is compressed and deep. The snout is rounded and the eye is markedly in the anterior half of the head. The snout projects slightly beyond the upper lip and mostly obscures it. The mouth is slightly subterminal and oblique. Lips are well-developed but not fleshy, the upper lip is thinner than the lower, and the lower lip is interrupted in the middle. The dorsal fin spine is moderate and lacks denticles. The last third or quarter of the dorsal fin spine is thin, flexible and tapering. The dorsal fin is emarginate and its origin is slightly posterior or anterior to the level of the pelvic fin origin. The depressed dorsal fin reaches back to, or not to, the level of the anal fin origin, both conditions in fish of the same size. The caudal fin is moderately forked with rounded lobes, the lower more rounded than the upper lobe. The anal fin is emarginate and does not extend back to the base of the caudal fin. The pelvic fin margin is rounded to straight and falls short of the

anal fin origin or almost reaches it. The pectoral fin is rounded and does not extend back to the pelvic fin origin.

Dorsal fin with 4 unbranched and 7-9, usually 8, branched rays, anal fin with 2-3 unbranched and 4-5, usually 5, branched rays, pectoral fin branched rays 13-19, usually 16-17, and pelvic fin branched rays usually 8. Lateral line scales 29-37. A small pelvic axillary scale may be present or scales in this area may be so weakly-developed as not to be an apparent axillary scale. Scale shape is squarish with straight to gently rounded dorsal and ventral margins and a rounded posterior margin. The anterior margin may have a central protrusion with an indentation above and below or be wavy. The anterior corners are rounded to pointed. Scales have a slightly anterior focus, fine concentric circuli, many radii on all fields and the posterior, exposed field bears numerous small tubercles. Lateral field radii may be very curved. Total gill rakers number 13-19, reaching the raker below or just beyond when appressed. Pharyngeal tooth formula is 2,3,5-5,3,2, sometimes with only 4 teeth in the main row but the anterior tooth is missing in both small and large fish and so does not appear to be age related. Teeth are hooked at the tip but not strongly on the posterior main row teeth which are spoon-shaped with the hollow of the spoon filled in with bone. The gut has several loops, two anteriorly and three posteriorly. Total vertebrae number 38-42 (lower values in the literature, 38-39, may not include the hypural plate). Chromosome number 2n = 98 (Balasem *et al*., 1994).

Microscopic studies of the pharynx and oesophagus have been carried out by Alboghobeish and Moosavi (1998) who confirmed that this species is adapted for herbivory. Alboghobeish and Hamidian (2006) studied the distribution of alarm cells in the skin. Abdullah (2016) described the osteology of the premaxilla, maxilla, lower jaw and operculum. Kiarsi Alikhani *et al*. (2019) described the allometric growth pattern and morphological changes during early ontogeny.

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(2), anal fin branched rays 5(2), pectoral fin branched rays 16(2), pelvic fin branched rays 5(2), lateral line scales 30(1) or 31(1), total gill rakers 16(1), 17(-) or 18(1), pharyngeal teeth 2,3,5-5,3,2(2), and total vertebrae 41(7) or 42(7) (vertebrae based on two syntypes above (one with fusions not counted) and Iranian and Iraqi fish: CMNFI 1979-0087, CMNFI 1987-0017, BM(NH) 1874.4.28:27, BM(NH) 1875.1.14:16, BM(NH) 1920.3.3:71-75, BM(NH) 1973.5.21:195-196).

**Sexual dimorphism.** Males have shorter pelvic fins than females, the distance between the pelvic and pectoral fins is shorter and the head length is shorter based on fish from Lake Razzazah, Iraq (Al-Hakim *et al*., 1976)

**Colour.** Overall colour is greenish to light brown or golden brown with the belly white to silvery or yellowish-brown. Scales on the back and uppermost flank have solid dark brown pigment on the exposed part of the scale. The scale edge is thinner and so appears lighter and scales are demarcated. The iris is brownish-orange, golden or silvery. Fins are darker than the adjacent body, a deep reddish-brown, with melanophores on rays and membranes in preserved fish. The peritoneum is black.

**Size.** Attains 55.0 cm and 4.0 kg (van den Eelaart, 1954; Al-Hamed, 1966b, 1972). In Khuzestan reaches at least 3.5 kg (J. Gh. Marammazi, pers. comm., 1995) and 37.4 cm (Hashemi *et al*., 2015).

**Distribution.** This species is found in the Tigris-Euphrates River basin and the Persis basin. In Iran it is reported from the northern Persis basin in the Zohreh River; and in the Tigris River basin in the Hawr al Azim and in the Arvand, Bahmanshir, Dez, Hofel, Jarrahi, Kahnak,

Karkheh, Karun, Khorramabad, Marun, Nahr Shavar, Shate Neisan and Zard rivers (Marammazi, 1995; Abdoli, 2000; Khoshnood, 2014; Darabi *et al*., 2015; Fatemi *et al*., 2019). It has also been translocated to the Kor River basin (Teimori *et al*., 2010; Esmaeili *et al*., 2015; Khamees *et al*., 2019).

**Zoogeography.** Karaman (1971) considered that this species originated from the Indian line of the Torini, a tribe of Cyprinidae, in which Karaman included such genera as *Carasobarbus* and *Kosswigobarbus* (= *Carasobarbus*) and *Garra* which have Iranian members, and *Hemigarra* (once recognised as *Hemigrammocapoeta*, now in *Garra*). Borkenhagen (2005, 2017a) was not able to resolve the split between *Arabibarbus*, *Carasobarbus* and *Mesopotamichthys* of the Torini in Iran but supposed it happened in the late Miocene or Pliocene. The Torini originated in Indomalaya and colonized Africa via the Middle East. The Iranian Torini have their sister group in Africa (*Labeobarbus*). Abasi Dehkord *et al*. (2018) used the COI gene and concluded this species affinities lie with oriental species such as *Tor* and it is closely related to *Arabibarbus grypus*.

**Habitat.** This species is found in rivers, marshes, dams and brackish environments. Marammazi (1994) considered this species as stenohaline and so restricted in its distribution in the Zohreh River that drains to the northern Persian Gulf (Persis basin). The influence of salinity on growth rate was examined by Orian *et al*. (1993). However, Salman *et al*. (1995) found that this species survived well in saline water from the Saddam River, Iraq fed into concrete ponds. A survival rate greater than 70% was found at 10-19‰. Morovvati *et al*. (2017a, 2017b) found that the gills and kidneys of this fish adapted to increasing salinity to which it was tolerant. A concentration of 4 p.p.t. was optimum but concentrations of 8 and 12 p.p.t. were tolerable. Morovvati *et al*. (2017) showed that varying salinity concentrations influenced the skin on the head, the lateral line, epidermis thickness, and the number of club cells decreased while goblet cell number increased.

van den Eelaart (1954) and Al-Hamed (1966b, 1972) reported some movement from lakes and marshes, from the end of February to the beginning of March, to rivers in the Tigris-Euphrates basin of Iraq during floods for about three weeks. There was a return to lakes and marshes for spawning in mid-March to mid-April. However, most fish remained in marshes and lakes for most of the year, in overgrown areas avoiding open water. Low water levels and high temperatures in the lakes and marshes may cause a migration to their deepest parts or into the lower reaches of the main and more permanent rivers. This species was less tolerant of low oxygen than *Luciobarbus xanthopterus* and that probably accounts for them not being caught together in any number.

**Age and growth.** Hashemi *et al*. (2010a, 2010b) for 237 fish gave a length at maturity ($L_M$) of 28.6 cm, production per biomass (P/B) of 0.4, $L_\infty$ of 44.9 cm, K of 0.25 $yr^{-1}$ and $t_0$ of -0.33 $yr^{-1}$ for fish from the Shadegan Wetland or Marsh in Khuzestan. Hashemi *et al*. (2015) found length-weight relationships in 437 fish from the Shadegan Wetland were $W = 0.000006L^{3.11}$ for males and $W = 0.000005L^{3.14}$ for females. Length at maturity for males and females was 20.8 cm and 22.0 cm, weight at maturity was 97g and 133 g, and production per biomass was 0.53 and 0.5 per year. Growth was isometric in a study on 413 fish from Khuzestan by Sharifian (2016a).

Al-Hakim *et al*. (1976) studied some aspects of the biology of this species in Razzazah Lake, Iraq. Females were longer and heavier than males at advanced ages. Life span of females was 9 years and for males 8 years. Maturity started in the third year at 32-35 cm total length. Males matured earlier than females. Jiad and Hameed (1986) also found 9 age groups in Iraq.

Al-Hamed (1966a, 1966b, 1972) found Tigris River fish in Iraq to mature at 25 cm for males and 28 cm for females in the second year of life and spawning took place early in the third year. A few fish matured in age group 1 and some as late as age group 3. Males were somewhat more abundant than females on the spawning grounds, averaging 57.4% of the fish caught. Maximum age was 6 years. Ali (1982b) found this species to mature in the fourth year of life in Iraq, with growth better in the marshes than in Tharthar Reservoir. Barak and Mohammed (1985) reported 6 age groups from Basrah and weight-length relationship was log W = 11.426 + 3.0086 log L. Epler *et al*. (1996) found fish up to age $6^+$ years in fresh and salty Iraqi lakes. Nasir *et al*. (1989) reported on the biology of this species in the Al-Hammar Marsh, Iraq and found a female:male sex ratio of 1:3 for all months and length groups caught. No explanation for this skewed ratio was found. A comparison of growth rates in five localities by Hussein *et al*. (2000) showed similarities in the first 2 years of life, with later variations attributed to differing ageing techniques, sample size and fishing gear used. Growth in the Hawr al Hammar was better than in the Shatt al Arab and this was attributed to the more favourable environment for this species in the lake. Al Mukhtar *et al*. (2006) found 290 fish from Al-Huwaizah Marsh, Iraq, 26.1-53.5 cm total length, had an overall *b* value of 2.7097 but ranged from 3.27 in January to 1.93 in February. Al-Jubouri (2019) examined 393 fish, total length 12.0-38.5 cm, from the Al-Diwaniyah River, Iraq and found this species comprised 5.09% of the fish assemblage, $W = 0.0164L^{2.901}$, the sex ratio differed significantly from 1:1 in favour of females, mean values of relative condition factor for small fish, males and females were 0.92, 0.92 and 0.99, respectively, eight age groups were recognized with lengths 11.8, 21.4, 26.2, 30.5, 34.5, 37.8, 41.1 and 44.3 cm, length group 27 cm dominated, and von Bertalanffy growth constants were $L_\infty$ = 56.0 cm, K = 0.228 and $t_o$ = -0.103. The growth performance index (Φ) was 2.82. The total (Z), natural (M) and fishing (F) mortality rates were assessed by applying the length cohort analysis and were 0.85, 0.252 and 0.598, respectively. The exploitation rate (E) estimate was 0.703, exceeding the optimal level of exploitation (E = 0.5), so this fish stock was overexploited. The following report was presumably based, at least in part, on this thesis. Mohamed and Al-Jubouri (2020b) examined 396 fish, 11-39 cm total length from the Al-Diwaniya River, Iraq. The length-weight relationship was $W = 0.032L^{2.7017}$, negative allometric growth. Seven ages were identified from with mean lengths 11.8, 21.4, 26.2, 30.5, 34.5, 37.8 and 41.1 cm, respectively. von Bertalanffy growth parameters were $L_\infty$ = 56.0 cm, K = 0.229 and $t_0$ = - 0.103 years. The growth performance index (Φ) was 1.99. The overall male to female ratio (1:1.48) was biased in favour of females. Length at maturity was 33 cm for males and 34 cm for females. The monthly fluctuation in the relative condition factor of the species was influenced by the spawning cycle and feeding intensity of the fish.

**Food.** In the Karun River, diet included such plants as *Potamogeton*, *Salvinia*, *Nuphar* and *Phragmites* (*Annual Bulletin 1993-94, Iranian Fisheries Research and Training Organization, Tehran*, pp. 91-92, 1995). Sharifian (2016a) found Khuzestan fish to be herbivorous and omnivorous.

Al-Hamed (1965) found this species in Iraq to be strictly herbivorous, feeding on unicellular Chlorophyceae, diatoms and filamentous algae when young and on higher plants and detritus when older. Nasir *et al*. (1989) and Epler *et al*. (1996) confirmed that this species in Iraq was completely herbivorous although some copepods and molluscs were taken, most probably incidental to filamentous algae, diatoms and detritus. van den Eelaart (1954) reported feeding even in cold winters. Al-Jubouri (2019) and Mohamed and Al-Jubouri (2020b) found fish from the Al-Diwaniya River, Iraq were herbivorous and fed mainly on aquatic plants

(41.0%), algae (38.7%), detritus (13.3%), and diatoms (6.5%). The highest feeding overlap (0.93) was found between *Mesopotamichthys sharpeyi* and *C. luteus*. This species was a low specialised feeder (0.48).

**Reproduction.** Petr (1987) reported spawning in Iran at 15-16°C in February in clean water of rivers with sandy bottoms. In the Karun River this species spawned in March-April in river estuaries (*Annual Bulletin 1993-94, Iranian Fisheries Research and Training Organization, Tehran*, pp. 91-92, 1995). A specimen caught in March 1971 had well-developed testes (CMNFI 1979-0087). Spawning in Shadegan Marsh, Khuzestan was in March and in branches of the Karkheh River in March to April (Al Mukhtar *et al*., 2006). Hashemi *et al*. (2015) however, found spawning in the Shadegan Marsh occurred from April to July. Shadegan Marsh is one of the most important spawning areas in Iran (Mohammadi and Marammazi, 2001). Mohammadiyan *et al*. (2014) found the highest levels of steroid hormones in winter, indicating spawning then. Khodadadi *et al*. (2011) and Ahmadi *et al*. (2013) gave details of larval development in Khuzestan under controlled conditions, noting that it is similar to other *Barbus s.l.* species.

van den Eelaart (1954) and Al-Hamed (1966b, 1972) studied reproduction in this species on the Tigris River in Iraq and Al-Nasih (1992) in fish ponds. Spawning occurred chiefly in lakes and marshes, with some spawning in the lower reaches of rivers. Eggs were deposited on submerged, or partially submerged, vegetation, from the surface down to about 1 m depth. Eggs were large, yellow and measured up to 1.7 mm in diameter and numbered up to 158,000. Epler *et al*. (1996) gave a relative fecundity of 10,021 to 28,471 eggs for fish $4^+$ to $6^+$ in age from Iraqi lakes with fish spawning in April in a freshwater lake and February/March in a saline lake. The spawning season in Lake Saniyah just north of Amara was March and April, with some ripe fish caught in May. Fish appeared on the spawning grounds about sunset and left before darkness was complete. They returned in the early morning and left again at about 0800 hours. These fish chased each other, darted about singly or in pairs, and sometimes came to the surface and splashed. Al Mukhtar *et al*. (2006) investigated this species in the Hawizeh Marsh as a source of spawners for aquaculture. Ripe eggs appeared in January and 25% were running in February and 30% in March. Half of the fish were spent in April. The spawning migration was led by males in October and December with females increasing rapidly in February. Males disappeared in April. Absolute fecundity reached 236,160 eggs. Fish spawned in March and April. A migration of smaller fish, mostly males, was followed by a rush of larger fish, mostly females, as shown by changes in sex ratio. The gonadosomatic index increased from December to March for females while for males it reached a maximum in February. Absolute fecundity reached a maximum of 236,160 eggs and relative fecundity 134.26 eggs/g body weight. Al-Rudainy (2008) gave an absolute fecundity of up to 358,343 eggs in Iraq or up to 145 eggs/g body weight and an egg diameter of 2.0 mm. For fish from Al-Diwaniya, Iraq the gonadosomatic index (9.79 for females and 6.32 for males) was at the highest level in April then dropped dramatically for both sexes, suggest that the species may spawn in late April to May (Al-Jubouri, 2019; Mohamed and Al-Jubouri, 2020b).

Al-Nasih (1992) and Mukhaysin and Jawad (2012) gave details of larval development. Histological characters of the ovary and testis at different ages were detailed by Dastegir *et al*. (2013, 2013) who determined development was asynchronous in Shadegan Wetland fish.

**Parasites and predators.** Bykhovski (1949) reported a new species of monogenetic trematode, *Dactylogyrus pavlovskyi*, from this species in the Karkheh River, Iran. Ebrahimzadeh and Nabawi (1975) listed species of the protozoans *Trichodina* and *Myxosoma*

and the trematode *Dactylogyrus* as well as the nematode *Camallanus lacustris*, from this fish in the Karun River.

Jalali and Molnár (1990a) recorded two monogenean species, *Dactylogyrus* spp., in the Dez River and Molnár and Jalali (1992) a new species of monogenean, *Dogielius persicus*, from this species in the Dez and Karun rivers of Khuzestan. Moghainemi and Abbasi (1992) recorded a wide range of parasites from this species the Hawr al Azim in Khuzestan. Gussev *et al*. (1993b) recorded *Dactylogyrus pavlovskyi* in the Dez River. Masoumian *et al*. (1994) described a new species of Myxosporea from the gills of fish in the Karun River, namely *Myxobolus persicus*. Peyghan (1994) reported ichthyophthiriasis in cultured *Barbus* (= *Mesopotamichthys*) *sharpeyi* in Khuzestan. This parasite causes severe skin and gill damage and mortality reached 80%. A combination of formalin and malachite green, with transfer of fish to another pond having a better environment, cured the condition. Masoumian *et al*. (1996a) described a new species of Myxosporea, *Myxobolus bulbocordis*, from the heart of fish caught at various localities in Khuzestan and later (Masoumian *et al*., 1996b) another new species of Myxosporea, *Myxobolus nodulointestinalis*, in the gut lining, also from rivers of southwestern Iran. Molnár and Pazooki (1995) recorded philometrid nematodes from this species in the Karun River, and these were presumed to be a new species. Pazooki and Molnár (1998) later described *Philometra karunensis* as the new species from the gas bladder and abdominal cavity. Molnár *et al*. (1996) reported additional new species from this fish in Khuzestan, namely *Myxobolus iranicus* in the spleen and *Myxobolus sharpeyi* in the gill cartilage. Myxosporeans are potentially dangerous to fishes such as *Mesopotamichthys sharpeyi* that may be used in fish culture in Khuzestan. Masoumian and Pazooki (1999b) listed *Myxobolus bulbocordis, M. iranicus, M. karuni, M. nodulointestinalis, M. persicus* and *M. sharpeyi* from this species in various localities in Khuzestan.

The monogeneans *Dactylogyrus anchoratus*, *D. barbioides*, *D. carassobarbi* and *D. pavlovskyi* and *Dogielius persicus* were recorded from this species in the Karun River with heavier infestations in spring and summer than in autumn and winter. These gill parasites caused no serious injuries but were thought to be important in respect of monitoring infestation levels on fish farms in Khuzestan (www.avz1.8m.com/fulltext.htm, downloaded 28 October 2002). Papahn *et al*. (2004) recorded the monogeneans *Dactylogyrus anchoratus, D. barbioides*, *D. carassobarbi* and *D. pavlovskyi* and *Dogielius persicus* from this species in the Karun River at Ahvaz. Mokhayer *et al*. (2006) collected this species from four sites in Shadegan Marsh and found *Dactylogyrus anchoratus, D. carassobarbi* and *Dogelius persicus*. The first species had more parasites in the right gill compared to the left gill, the second had more in the upper holobranch and the third more in the lower holobranch. Mortezaei *et al*. (2007) found the nematode *Rhabdocona denudata* in fish from Shadegan Marsh, Khuzestan. Barzegar *et al*. (2008) recorded the digenean eye parasite *Diplostomum spathaceum* from this fish. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Argulus* sp. and *Ergasilus sieboldi* on this species. Shamsi *et al*. (2009) found *Dactylogyrus anchoratus* in farmed fish and the Karun River. Rahdar *et al*. (2012) collected fish from Shadegan and Susangerd and found *Dactylogyrus pavlovskyi, Ichthyophthirius multifilis, Contracaecum* sp., *Balantidium* sp., *Myxidium rhodei* and *Sarcocystis*-like organisms. They recommended that raw or undercooked fish from this region of Khuzestan be avoided. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Neoechinorhynchus tylosuri* from fish in Khuzestan. Mohammadi *et al*. (2019) reported *Diplostomum spathaceum* from the eyes and Bothriocephalidae, *Anisakis, Contracaecum*, *Khawia*, *Neoechinorhynchus* and

*Varelacreptotrema* from the gastro-intestinal tract of fish from Shadegan Wetland. Moumeni *et al*. (2020) recorded the zoonotics *Anisakis* spp., *Contracaecum* spp. and *Philometra karunensis* from this fish in Iran.

Nikbakht *et al*. (2007) examined the structure and distribution of gut associated lymphoid tissue, important in diagnosis and control of disease in aquaculture, as well as for vaccination.

**Economic importance.** Petr (1987) suggested investigating fish farming of this species in Khuzestan and Al-Nasih (1992), Al Mukhtar (2009) and Al-Noor *et al*. (2012) carried out such an investigation and means of spawning induction for Iraq (see below). Yazdipour *et al*. (1991) reported on propagation of this species in Iran. The biology of this species has been investigated in Khuzestan with a view to aquaculture (*Annual Report, 1994-1995, Iranian Fisheries Research and Training Organization, Tehran*, p. 6, 1996). The Khuzestan Fisheries Research Centre at Ahvaz has successfully bred this species in pond and pen culture using hormone stimulation of broodstocks (Emadi, 1993a; *Iranian Fisheries Research and Training Organization* pamphlet; *Iranian Fisheries Research and Training Organization Newsletter*, 5:2, 1994; *Annual Report, 1994-1995, Iranian Fisheries Research and Training Organization, Tehran*, p. 49, 1996; Mohammadian *et al*., 2009) and in polyculture with Chinese carps such as *Ctenopharyngodon idella* (*Annual Bulletin 1993-94, Iranian Fisheries Research and Training Organization, Tehran*, pp. 93-94, 1995; *Annual Report, 1995-1996, Iranian Fisheries Research and Training Organization, Tehran*, pp. 36-37, 1997). Private companies also cultured this species in Khuzestan. In Khuzestan, over 95% of young survived, using hormones to stimulate reproduction. Kazemi (2009) investigated the effect of different ratios of carbohydrates to dietary fat on growth indicators, nutrition and fish body composition. Kahkesh *et al*. (2010) studied the effect of ovaprim, ovatide, HCG, LHRH-A2, LHRHA2+CPE and carp pituitary on artificial breeding and found the LHRHa2+CPE combination was effective. Moosavi *et al*. (2015) briefly mentioned artificial breeding in Khuzestan and the similarities and differences between this species and *Arabibarbus grypus*. Ahmadi *et al*. (2013) described embryonic development. Hamidinezhad *et al*. (2016) studied the biotechnique of artificial breeding of this species in Khuzestan using 400 female and 200 male broodstock with 70% of females and 65% of males responding to hormonal treatment. Survival rates of 1 g and 7 g larvae were 16% and 40%. A good resistance to oxygen and temperature changes during artificial breeding indicated this species is a good candidate for aquaculture in Khuzestan. Jerfi (2016) examined hydrothermal shock as a means of inducing triploids for aquaculture. Sharifian (2016b) examined native aquaculture of this species in Khuzestan based on data over three decades. Despite a low relative growth rate, it was a desired market fish, and it does have a high fecundity and feeds on phytoplankton during the larval stages. Kamali Sabeti (2021) gave an overview of the characteristics and physiology of this species.

Al-Nasih (1992) investigated the use of this popular food fish for aquaculture in Iraq. Although its growth rate is slower than in *Cyprinus carpio*, a popular fish for aquaculture, its plankton feeding makes it adaptable to pond life without competition with *Cyprinus carpio*, it has tasty flesh, reaches 2.0 kg, and has a relatively high fecundity. Hormonal injections with hypophysial extract from the more readily available *Cyprinus carpio* induced breeding in this species. Natural production could be increased to 450-600 kg/ha with the use of mineral fertilisers in ponds to stimulate plankton growth. Al Mukhtar (2009) detailed hatchery construction and propagation planning in Iraq. A total weight of 30.0 kg of females could produce 0.61 million first feeding fry. Al-Noor *et al*. (2012) gave details of the technical steps

for the induced spawning of this species in Iraq. The best time was from the first week of March to the last week of April, hormonal dosages were detailed, an average of 1,800 g of fertilised eggs were obtained from each female, the best brooders were females 750-1,000 g and males 500-900 g, and the best hatching temperature was 22-24°C.

This species is second in importance after sobour or Indian shad (the clupeid *Tenualosa ilisha*) at the Basrah fish market in Iraq, with a weight from October 1975 to June 1977 of 772,775 kg. Nasir *et al*. (1989) recorded a total catch for Iraq of 5,000 tonnes per year and Petr (1987) for Iraq in 1976 a catch of 4,243 t. Young (1976) noted that this species was regarded as the tastiest fish available from the marshes of Iraq. van den Eelaart (1954) gave the fishing season for this species as February-May (peaking in March) in rivers and January-July (peaking in March-April) for lakes and marshes. Ali (1980) recommended a mesh size of 45 mm for the fishery based on an average length coefficient of 0.14. It is a popular food fish in Khuzestan (Hashemi *et al*., 2017).

**Experimental studies.** Arzi *et al*. (2009, 2011) compared organochlorine residues in this species in three cities in Khuzestan and found residues of 14 pesticides. Taravati *et al*. (2012) found cadmium, lead and mercury concentrations in fish from the Shadegan Wetland or Marsh were higher in some tissues than accepted standards for human consumption. Abdi and Alishahi (2014) showed that the pesticide diazinon was toxic to this species and toxicity increased with pesticide concentration. Alishahi *et al*. (2016) determined the acute toxicity of sublethal concentrations of diazinon pesticide and the haemato-immunological responses of this fish under experimental conditions. Chronic sublethal concentrations of diazinon would affect survivability of this fish in the wild and in aquaculture. Tabandeh *et al*. (2014) and Mohammadiyan *et al*. (2019) examined tissue distribution and activity of rhodanese, a mitochondrial enzyme that detoxifies cyanide, in fish from the Karun River. This data could then be used to assess severity of cyanide contamination of water or fishes. Tabandeh *et al*. (2014) found mercaptopyruvate sulphur transferase, a cyanide-detoxifying enzyme, in tissues of this species. Jaddi *et al*. (2014) found the maximum acceptable toxicant concentration of the herbicide paraquat was 0.14 mg/l, and lethal toxicity takes place in a narrow range of toxicant concentrations. Koohkan *et al*. (2014) showed that paraquat caused lesions in the liver of fingerlings and Hashemi *et al*. (2017) found that paraquat had significant effects on haematological and biochemical parameters and could cause risk to growth and survival.

Saligheh Zadeh *et al*. (2014, 2015) determined that supplementing the diet of fingerlings with the cyanobacterium *Spirulina* (= *Arthrospira*) *platensis* at 10% improved final weight, weight gain, specific growth rate, condition factor and body protein content, and led to increases in immune indices and lysozymes. Sharibi *et al*. (2015) found that 0.2 g/kg of the probiotic bactocell added to the diet of fingerlings improved growth and nutrition efficiency. Seiedzadeh *et al*. (2015, 2016) showed that the use of 4-6% chicken egg lecithin in the diet of juveniles had positive effects on promoting growth, health status, survival and resistance to thermal shock. Yadkoori *et al*. (2015) showed that the addition of 1% ginger extract to the diet of fingerlings enhanced growth. Zakeri (2018) examined the effects of a dietary supplementation with a synbiotic finding different levels could improve growth, feeding performance, weight, feed conversion ratio, food and protein efficiency ratio, and body biochemical composition by increase in protein content. Optimum results were achieved at 1.5 g/kg for weight gain, feed conversion ratio and body biochemical composition. Mohammadi Nefchi *et al*. (2019) showed that replacement of fish meal with soybean and baker's yeast could be used up to 100% without a negative effect on juvenile diet.

Basak Kahkesh *et al*. (2010) cultured this species with Chinese carps in earthen ponds in Khuzestan harvesting 4,976 and 5,993 kg/ha in two treatments. Bosak Kahkesh *et al*. (2010) investigated the hormones ovaprim, ovatide, HCG, LHRH-A2, LHRHA2+CPE and common carp pituitary extract for stimulation of ovulation, finding that a combination of LHRHA and carp pituitary extract was most effective. Bosak Kahkesh *et al*. (2012) found that female broodstock 1,350±350 g, 2.5±0.5 years and 47.92±4.63 cm had the maximum working fecundity (33,000±1,450 eggs) in artificial propagation. Mabudi (2011) and Mabudi *et al*. (2011) investigated the histology and hormonal effect of the hormone ghrelin on the ovary, finding positive effects on oocyte maturation, vitellogenesis, the number of mature follicles, and fertilisation, hatch percentage and sexual maturation while reducing the average oocyte diameter. Ahmadi *et al*. (2013) studied the development and growth of laboratory-reared larvae, the larvae starting to swim with 2-3 days and the yolk sac totally absorbed within 4-5 days after hatching. Ahmadi *et al*. (2014) detailed the embryogenesis of this species as a useful tool for understanding the timing and suitable conditions for spawning and growth and the techniques necessary to increase growth and survival. Mohammadiyan *et al*. (2014) found that using LHRH-a2 hormone combined with common carp pituitary extract led to high spawning and fertilisation success and weight of the stripped egg mass in Khuzestan fish. Bosak Kahkesh (2016) surveyed different dietary energy and protein levels on reproduction indices in broodstock. Twelve female brooders were transported to 300 sq m earthen ponds. They were fed two times each day for four months until satiation. Artificial breeding was carried out in spring for a survey of reproductive indices. The amount of hypophysis injection was 3mg/kg weight of fish with two doses, 10% in the first stage and 90% in the second stage, with an interval of 10 hours. The male broodstock injection was first stage spontaneously with second female injections with a dose of 2 mg/kg. Until larvae release, temperatures registered 22.5-24.5°C. Results showed that constant protein (35%) with rising energy until a specified amount (350 Kcal/100g) increased reproductive indices. The working fecundity was one of the reproductive indices that in one treatment had a significant difference compared to other treatments. In this survey. Khorasaninasab *et al*. (2020) recommended a stocking density of 5,000 eggs/l as higher levels resulted in significant reduction in survival but had no significant effect on water quality parameters. The effects of egg stocking density on survival and on antioxidant and health status of embryos, newly hatched larvae and exogenous-feeding larvae were examined.

Sharifian (2006) gave details of whole-body analysis. The highest protein content was in the 30-95 mm and 100-140 mm length groups. Sharifian (2014) determined the proximate composition (protein, lipid, ash, phosphorus, calcium, amino acid profile) of the carcass at different sizes in fish from the Shadegan and Hawr al Azim wetlands. Javaheri Baboli and Darvishi *et al*. (2016) compared cultured and wild fish for fatty acid profiles, finding cultured fish muscle and liver had higher levels of polyunsaturated fatty acids (PUFA) whereas wild fish muscle had a higher level of saturated fatty acids, Cultured fish can be a healthy component in the human diet. Hosseini Najd Gerami (2018) determined seasonal variations in liver and muscle fatty acid composition, finding the highest amount of PUFA and omega-3 fatty acids in spring for muscle and summer for liver tissue. Fekrandish *et al*. (2021) studied the effects of antioxidant and antibacterial coatings of sodium alginate, carrageenan and savory essence (*Satureja khuzistanica*) to increase burger maintenance during storage at 4±1°C, results showing that 1% sodium alginate solution, 1% carrageenan solution and 1.5% savory essence treatment had a better performance than a control and other treatments.

Kalbassi *et al*. (2013) showed that saline activator solutions extended sperm movement time in Khuzestan specimens, an advantage with this species that has a low fertilisation rate. Kalbassi *et al*. (2014) found that the LHRH-a2 hormone combined with dopamine antagonist and common carp pituitary extract gave the highest sperm quality at LHRH-a2 (10 μg/kg + dopamine), at LHRH-a2 (5 μg.kg + dopamine) and LHRH-a2 (5 μg/kg) at 8, 12 and 16 hours respectively. Kalbassi *et al*. (2015) showed that injections of luteinising hormone-releasing hormone analogue (LHRH-a) and metoclopramidae improves spermatogenesis compared to using common carp pituitary extract. Testis histology and sperm morphology were also described.

Khadjeh *et al*. (2007) and Khajeh *et al*. (2008) examined haematological parameters in cultured fish and found some to be higher than in *Ctenopharyngodon idella*. Khodadadi *et al*. (2009) evaluated serum parameters of brood stock during the spawning season. Ansari *et al*. (2011) studied immunoglobulin M and found that weight, length and sex influence levels and so need to be taken into account when using it to measure stress and disease, smaller fish and males being more susceptible. Javaherzadeh Dezfool *et al*. (2012) studied different levels of dietary vitamin C on immunological and haematological parameters concluding, in part, that supplementation of food with 400, 800 and 1,600 mg/kg could stimulate the immune response. Dayer *et al*. (2014) used this species as a model for studying oxygen release in fish haemoglobin, showing that this protein has a higher oxygen affinity than human haemoglobin, enabling the fish to cope with poor environmental conditions. Mesbah *et al*. (2015) studied salinity effects on haematological parameters and cortisol levels, with a significant decrease in red blood cells at 12 g/l, and highest cortisol at 4 g/l and lowest at 8 g/l. Najafi *et al*. (2014) found that short-term starvation of fingerlings increased antioxidant enzyme activity in plasma, and did not cause disturbances in antioxidant defense status. Najafi *et al*. (2015) studied fasting and re-feeding that reduced flesh lipid and improved product quality, and had economic benefits, finding that 16 days fasting and then re-feeding had no adverse effect on haematological and immune indices. Asadi *et al*. (2016) found ginger extract (*Zingiber officinale*) in the diet did not significantly affect growth indices but significantly increased white blood cell count, haematocrit and some haematological parameters, as well as serum lysozyme activity, serum total protein and albumin.

Mortezazadeh *et al*. (2009) studied the effects of propofol as an anaesthetic on cultured fish. Mousavi *et al*. (2013) determined that concentrations of 1 p.p.m. and 40 p.p.m. of eugenol were best for decreasing stress (sedation) and anaesthesia induction respectively. The drug was moderately toxic and appeared to be a safe anaesthetic. Nazari *et al*. (2015a) investigated handling stress on fingerlings in aquaculture, in this case exposure to air for 60 seconds, finding biochemical and haematological responses. Nazari *et al*. (2015b) showed that fingerlings could be transported safely at the high density of 120 g/l without significant changes in physiological status. Broon *et al*. (2021) compared the effective doses of clove powder, 2-phenoxyethanol and PI222 as anaesthetics. The results showed that the best dose for clove powder was 150 mg/l, 2-phenoxyethanol was 350 p.p.m. and PI222 was 100 p.p.m. An inverse relationship was observed between the dose of anaesthetic and the duration of anaesthesia, so that with increasing dose, the induction time of anaesthesia decreased, while the recovery time was not related to the dose. Among the anaesthetics, clove powder and PI222 were more effective in lower doses and were more ideal anaesthetics.

**Conservation.** Local fishermen in Khuzestan believed numbers of this species declined in the Shadegan Marsh after young *Hypophthalmichthys molitrix* from the Caspian were

released. Several hundred thousand juveniles have been introduced into the Hawr al Azim in Khuzestan in order to restock and protect this resource (Network of Aquaculture Centres in Asia, downloaded 11 January 2007) and Mohammadian *et al*. (2009) listed production of 1-5 million 1-2 g fry used to restock Hawr al Azim and Shadegan Marsh annually. Bosak Kahkesh *et al*. (2010) recorded up to 3.5 million fry of average weight 1 g were released into the Hawr al Azim annually.

Smith *et al*. (2014) listed it as Vulnerable, overfishing being the principal threat. Listed as Vulnerable by the IUCN (2015) through marsh destruction, dam construction reducing water flows to lowland marshes, overfishing, and negative effects of the exotic cichlids *Oreochromis aureus* and *Tilapia zillii*.

**Sources.** Type material:- *Barbus sharpeyi* (BM(NH) 1874.4.28:20, BM(NH) 1874.4.28:27 and BM(NH) 1875.1.14:16) and *Barbus faoensis* (BM(NH) 1888.5.17:4).

Iranian material:- CMNFI 1979-0087, 1, 228.0 mm standard length, Khuzestan, Karun River at Ahvaz (31º19'N, 48º42'E); CMNFI 1991-0154, 1, 277.8 mm standard length, Khuzestan, Hawr al Azim (ca. 31º45'N, ca. 47º55'E); material observed on market stalls in Ahvaz, Khuzestan.

Comparative material:- CMNFI 1987-0017, 146.0-175.4 mm standard length, Iraq, vicinity of Basrah (no other locality data); BM(NH) 1874.4.28:27, Iraq, Tigris River near Baghdad (x-ray only), BM(NH) 1875.1.14:16, Iraq, Tigris River (x-ray only), BM(NH) 1920.3.3:71-75, 17, 58.7-115.0 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1920.3.3:76-77, 1, 261.4 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1922.5.24:1, 1, 113.5 mm standard length, Iraq, Basrah (30º30'N, 47º47'E); BM(NH) 1973.5.21:195, 1, 185.5 mm standard length, Iraq, Shatt-al-Arab (no other locality data); BM(NH) 1973.5.21:196, 1, 186.1 mm standard length, Iraq, Shatt-al-Arab (no other locality data).

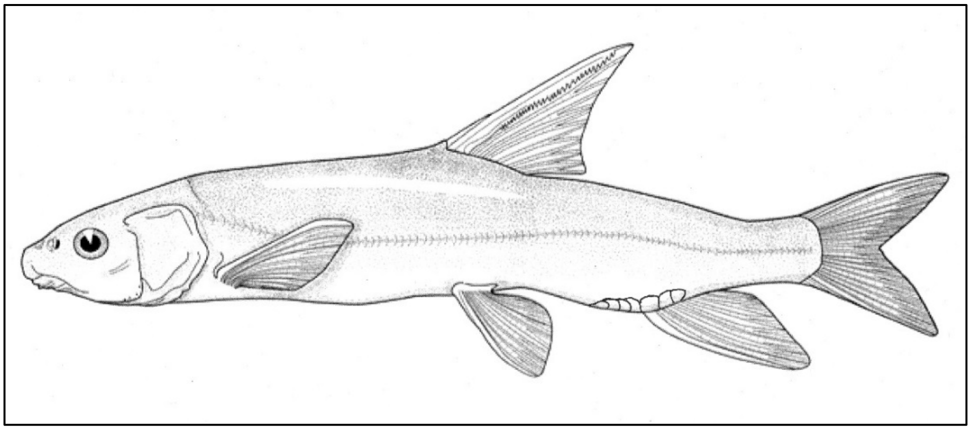
## Genus *Schizocypris*
Regan, 1914

This genus of medium-sized snow trouts or snow barbs contains only two species found in Pakistan, Afghanistan and Iran. Coad and Keyzer-de Ville (2005) revised the genus.

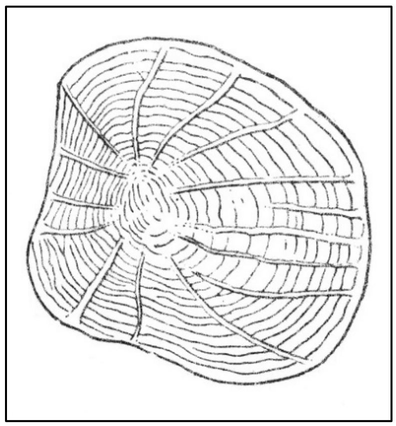
It is characterised by a rounded and moderately elongate body, scales small but larger near the shoulder region, belly scaleless, a wide and transverse mouth with the snout projecting, no barbels or barbels vestigial, pharyngeal teeth with a flat tip unlike *Schizothorax* and a formula of 2,3,4-4,3,2 rather than 2,3,5-5,3,2 as in *Schizothorax*, dorsal and anal fins short but 6 anal fin branched rays not 5 as in related genera in the same area, dorsal fin with a strong and strongly serrated spine, scales in the vent region are split and enlarged to flank the urogenital region and the anterior anal fin base, and radii are on all scale fields.

Rainboth (1981) included *Capoeta trutta*, *Capoeta fusca* and *Capoeta nudiventris* (= *C. fusca*) in this genus but this is incorrect. These species show some enlargement of scales around the anus and anal fin region but it is not as marked and definitive as in true *Schizocypris* and other characters of the genus are absent.

### *Schizocypris altidorsalis*
Bianco and Banarescu, 1982



*Schizocypris altidorsalis*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Schizocypris altidorsalis* (as *S. brucei)* dorsolateral scale,
after Annandale and Hora (1920).

*Schizocypris altidorsalis*, Sistan, Keyvan Abbasi.

**Common names**. Gorgak (= small wolf), anjak or khaju (A. A. Pasand, pers. comm., 5 November 2000 but see under *Schizothorax zarudnyi* and *S. pelzami*).

[Highfin carp, gorgak].

**Systematics.** *Schizocypris brucei*, *non* Regan, 1914 (Annandale and Hora, 1920) is a

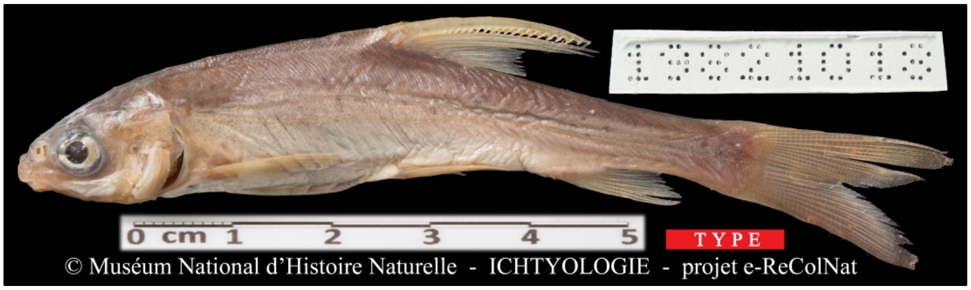
synonym. *Schizocypris brucei* Regan, 1914 is thus restricted to the Gomal River drainage in the Indus River basin of Pakistan (originally described from the Wana Toi, a Gomal River tributary). A third described species in the genus is *S. ladigesi* Karaman, 1969 from the Kankai River, also in the Indus River basin, is a synonym of *S. brucei* (Coad and Keyzer-de Ville, 2005).

Note that the author Banarescu is spelled without accents in the type description.

Jouladeh-Roudbar *et al*. (2020) have this species in the Leuciscidae part of their Iranian ichthyofauna paper although it is correctly placed in the appendix checklist.

Kähsbauer (1964) reported a hybrid between *Schizothorax schumacheri* and *Schizopygopsis stolickai* from Sistan that may in fact be this species.

The holotype of *Schizocypris altidorsalis* is in the Istituto di Zoologia dell'Universitá di L'Aquila, Italy under IZA 8169 and is 73.7 mm standard length (my measurement) (Bianco and Banarescu, 1982). The type locality is "Nahr-Taheri near Zabol, Seistan". Paratypes include five fish from the type locality under IZA 7841, 35-65 mm standard length (four fish seen by me, 35.4-62.0 mm standard length) with further specimens in the Institutul de Stiinte Biologice, Bucuresti, Romania (ISBB 3136). Three paratypes, 68-73 mm standard length, from "Rud-Sistan, 8 km from Zabol, Seistan" are under IZA 7844 (69.9-74.3 mm standard length) with further specimens under ISSB 3137. Two paratypes from the Nahr Taheri are in the Zoologischen Instituts und Zoologischen Museums der Universität Hamburg (ZMH 6091, 77.2-81.9 mm standard length) (Wilkens and Dohse, 1993), two paratypes are in the American Museum of Natural History, New York (AMNH 40952), one paratype is in the Muséum national d'Histoire naturelle, Paris (1982-1018), one paratype is in the United States National Museum, Washington (USNM 227928), two paratypes are in the Academy of Natural Sciences, Philadelphia (ANSP 150977), and two paratypes are in CMNFI 1982-0368 (formerly IZA 7841), appearing twice in the *Catalog of Fishes* (downloaded 22 May 2018), the second time under the old acronym NMC for National Museums of Canada, now Canadian Museum of Nature.




*Schizocypris altidorsalis*, paratype, MNHN-IC-1982-1018, L. Randrihasipara (CC BY 4.0).


*Schizocypris altidorsalis*, paratype, 66.4 mm standard length, CMNFI 1982-0368, Bronwyn Jackson @ Canadian Museum of Nature.

Syntypes of *Schizocypris brucei* are in the Natural History Museum, London under BM(NH) 1913.4.15:100-109 (10 fish) and in the Zoological Survey of India, Calcutta under ZSI F9832/1 (1) (Menon and Yazdani, 1968; Eschmeyer *et al*., 1996).

Berg (1949) advanced the possibility that this species is the juvenile of *Schizothorax zarudnyi* since barbels and scale cover develop with age. However, the tooth formula is very distinctive as is the anal fin branched ray count and lack of barbel development at all sizes in *S. altidorsalis* (Coad and Keyzer-de Ville, 2005). Gharaei *et al*. (2014) found that this species and *Schizothorax zarudnyi* are monophyletic and the sister group to *Mesopotamichthys sharpeyi* rather than *Luciobarbus* species, using cytochrome *b*.

**Key characters.** This species is characterised by a very high dorsal fin with a strongly denticulated spine. The spine is longer than the head and the denticles easily catch the skin when the fish are handled. This is particularly true of small fish; larger ones are not so snaggly. Bianco and Banarescu (1982) gave values for spine length of 24.4-29.8% of standard length in *altidorsalis*, 19.4-20.4% in *brucei*, and 14.7-19.5% in *ladigesi*. For 35 *altidorsalis* 66.1-175.1 mm standard length examined here, spine length is 23.3-31.3% of standard length and 14.0-18.5% for 20 *brucei* 102.3-170.8 mm standard length. Dorsal spine length in head length is 0.7-0.9, mean 0.9 for *altidorsalis*, 1.2-1.6, mean 1.4 for *brucei* (see also below). Scales in the lateral line are 87-96 (*brucei* has 74-81 and *ladigesi* 78-88) according to Bianco and Banarescu (1982). Specimens examined by me have lateral line counts of 81-95, mean 87.4, for 60 *altidorsalis* and 73-91, mean 79.6, for 56 *brucei*, showing some overlap but scales are definitely smaller on average in *altidorsalis*.

Bianco and Banarescu (1982) described the body as mostly scaled except on the anterior part of the breast (scaled on the mid-line of the back in front of the dorsal fin as in *ladigesi*, naked in *brucei*), and scales embedded on most of the body except the caudal peduncle and the lateral line; but see below.

**Morphology.** The body is rounded and elongate and relatively shallow, deepest at the dorsal fin. The dorsal profile in front of the dorsal fin falls gently to a rounded snout. The eye is at the end of the front half of the head. The mouth is inferior, transverse, and slightly arched. The caudal peduncle is compressed and moderately deep. The upper lip is covered mostly, but not entirely, by a rostral flap. The lower lip is developed only laterally. The lower jaw is covered by a horny sheath in some specimens, lost in others. There are usually no barbels (n = 105) although one fish, 70.1 mm standard length, had a minute pair of barbels hidden in the lip grooves and two other fish of similar size had respectively a single right and a single left

minute barbel. *S. brucei* has small but protruding barbels on both sides in 15 fish, a left barbel only in three fish, a right barbel only in five fish and no barbels in eight fish. The dorsal fin origin is anterior to the pelvic fin origin and when appressed almost reaches the anal fin. The dorsal and anal fin margins are concave. The caudal fin is moderately forked with rounded to pointed tips. The anal fin extends back to the caudal fin base or just short in young fish. The pelvic fin is rounded and remote from the anus. The pectoral fin is rounded and does not extend back to the pelvic fin origin.

Dorsal fin unbranched rays 3-4, branched rays 7-9, usually 8, anal fin unbranched rays 2-3, branched rays 5-6, usually 6, pectoral fin branched rays 12-20, and pelvic fin branched rays 7-10, usually 8. Since spines are often broken off, the height of the dorsal fin can be measured as the longest branched ray. For this species it is 16.5-28.8% standard length (mean 24.3, 60 fish) while in *S. brucei*, the taxon fish in Sistan were formerly assigned to, it is 11.6-20.0% (mean 16.8, 56 fish). Lateral line scales 81-96 (Jouladeh-Roudbar *et al*. (2020) gave 96-120 lateral line scales). Scales are regularly arranged over most of the body. In some fish, scales near the tail are difficult to distinguish. Shoulder scales are moderately large anteriorly above the lateral line and decrease in size posteriorly. The back is naked in a narrow band for a short distance anterior to the dorsal fin (not so according to Bianco and Banarescu (1982) but visible in fish examined by me). Flank scales are small but those at the dorsal fin base are a little larger. Lateral line scales are larger than those on the flank but only on the anterior lateral line. The breast is scaleless according to Bianco and Banarescu (1982) but is scaled on the breast in large specimens and some small ones too. There is a pelvic axillary scale. The scale focus is anterior with radii on all fields and, in overall shape, the scale is oval to rounded. Radii are found on all fields but are few in number (15). Total gill rakers number 24-30, reaching the third raker below when appressed in large fish but only one raker below in small fish. Pharyngeal teeth are usually 2,3,4-4,3,2(16) with variants 2,3,4-4,3,3(1), 2,3,5-4,3,2(2) and 2,3,5-4,4,2(1). The anterior main row pharyngeal tooth is peg-like while the rest are spatulate with a deep central groove and crowns flared on each side of the groove. The gut is very elongate and complexly coiled. Total vertebrae number 43-45 (Jouladeh-Roudbar *et al*. (2020) gave 48 vertebrae). The chromosome number is 2n = 48 with a fundamental arm number NF = 88 (Hedari Salkhordeh *et al*., 2016).

Meristic values for Iranian specimens are:- dorsal fin branched rays 7(2) or 8(38), anal fin branched rays 5(1) or 6(39), pectoral fin branched rays 14(1), 15(-), 16(11), 17(23), 18(4), 19(-) or 20(1), pelvic fin branched rays 7(1), 8(35) or 9(4), lateral line scales 81(1), 82(2), 83(3), 84(4), 85(6), 86(8), 87(10), 88(7), 89(5), 90(4), 91(3), 92(3), 93(3), 94(-) or 95(1), total gill rakers 24(1), 25(4), 26(5), 27(10), 28(12), 29(6) or 30(2), pharyngeal teeth 2,3,4-4,3,2(16), 2,3,4-4,3,3(1), 2,3,5-4,3,2(2) or 2,3,5-4,4,2(1), and total vertebrae 43(16), 44(33) or 45(11).

**Sexual dimorphism.** Unknown.

**Colour.** The back is bluish and the flanks and belly are silvery. The flanks may have a few to numerous small black spots and may also have a yellowish tinge. Fins have clear membranes with rays pigmented, the caudal fin being darkest overall. Pectoral and pelvic fins may be yellow to light orange.

**Size.** Reaches 17.5 cm standard length. Zare *et al*. (2011) gave a total length of 19.3 cm and Abbaspour *et al*. (2013b) 23.5 cm fork length.

**Distribution.** This species is endemic to the Sistan basin of Iran and Afghanistan including the Hirmand, Kharaji and Sistan rivers, the hamuns, ditches, jubes (= irrigation channels) and the Chahnimeh Reservoirs in Iran (Bianco and Banarescu, 1982; J. Holčík, *in*

*litt*., 1996; Latifi *et al*., 2018; Ghanbari *et al*., 2019). The distribution of this species (as *S. brucei*) in Khorasan and Gorgan reported by Wossughi (1978) is incorrect.

**Zoogeography.** A relative of other schizothoracine species found along the mountain chain from Iran to China. See also the genus *Schizothorax*.

**Habitat.** This species is found in rivers, streams, jubes (= irrigation ditches), lakes, dams, lagoons, pools, ponds and marshes (hamuns). It is reported from pools in dry river beds and still, reedy channels in Sistan. E. Penning (pers. comm., 28 July 2005) stated that this was the dominant fish species in Hamun-e Puzak and Hamun-e Saberi in April 2005 after a dry period when the hamuns flooded at the end of February. The fish enter the flooding hamuns from the upstream parts of rivers. In July, water levels fell from 1-2 m to less than 1 m and this species was absent, presumably having returned to the more permanent rivers. They were also observed swimming up a fish staircase at the Sistan Dam. Collection data included a temperature range of 22-31ºC (from 8-10 May 1977), pH 6.2-8.1, conductivity 0.51-1.0 mS, river width 2-120 m, still to fast current, depth 20-150 cm, cloudy or muddy water, a mud bottom, submergent and emergent vegetation (reed swamp), and a grassy shore.

Habitat of *Schizocypris altidorsalis*
(and *Garra rossica*, *Schizothorax zarudnyi* and *Tariqilabeo adiscus*),
CMNFI 1979-0226, Sistan, pool near Kuh-e Khajeh, 8 May 1977, Brian W. Coad.

**Age and growth.** Zare *et al*. (2011) gave length-weight *b* value of 2.972 for 37 fish, 12.5-19.3 cm in length, from the Chahnimeh Reservoirs, Sistan. Rahdari and Gharaei (2012) found *b* values of 2.0568 for females and 2.371 for males from the Chahnimeh Reservoirs, both negatively allometric. Fish studied by Abbaspour *et al*. (2013b) were all $1^+$ years.

**Food.** The principal food is aufwuchs and detritus as evidenced by the sectorial mouth and elongate gut. Gut contents are a fine mush (Abbaspour *et al*., 2013b). E. Penning (pers. comm., 28 July 2005) observed filamentous algae in the gut. Ghanbari *et al*. (2019) surveyed the bacterial communities in the gut using the 16S rRNA gene 454-pyrosequencing. The majority of sequences belonged to members of the Firmicutes, with also Proteobacteria, Tenericutes, Bacteroidetes and Cyanobacteria. The most abundant classes were uncultured CK-

1C4-19 class of Tenericutes, Flavobacteriia, α-Proteobacteria, Erysipelotrichi, Synechococcophycideae, γ-Proteobacteria, and Clostridia. The presence of many different types of bacteria was related to the detritivorous and planktivorous diet which has a higher microbial diversity compared to omnivorous and herbivorous fish species.

**Reproduction.** E. Penning (pers. comm., 28 July 2005) noted that fish at 20-30 cm caught in April 2005 had eggs 1.0 mm in diameter and were approaching or ready for spawning. Abbaspour *et al*. (2013, 2013b) found absolute fecundity to be 4,332.26 eggs, relative fecundity to be 69.83 eggs and egg diameter to be up to 1.25 mm, mean 0.83 mm.

**Parasites and predators.** Jalali *et al*. (1995) described a new species of monogenean, *Dactylogyrus schizocypris*, from fish taken in the Chahnimeh Reservoirs near the Hamun Lake in Sistan. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Lamproglena compacta* and *Lernaea* sp. on this species. Rahnama *et al*. (2017) examined 1,000 fish from the Chahnimeh Lakes or Reservoirs and Hamun Wetland and found an infestation rate of 61.1% with *Lernaea* spp., with seasonal differences and significant skin and muscle damage.

**Economic importance.** Individual fishermen caught 5-10 kg per day of this species in 2005 although they considered individuals as small and catches very low. Fish were 10-20 cm long with some larger ones at 20-30 cm (E. Penning, pers. comm., 28 July 2005; Penning and Beintema, 2006).

**Experimental studies.** Zolfaghari (2018) found lead concentrations in muscle tissue were higher than World Health Organization limits while mercury was lower. A maximum consumption of 0.020 kg/day gave no potential health risk. The maximum allowable fish consumption rate per month was 2.68 meals. Mirnia *et al*. (2019) found concentrations of copper, lead, nickel and zinc were higher than some international standards in fish from the Chahnimeh Reservoirs.

Rahimabadi *et al*. (2009) assessed the lipid quality of this species and found it to be less than that of *Schizothorax zarudnyi*. Zakipour Rahimabadi *et al*. (2009) gave chemical composition of muscles, noting variation by season and sex. Ganjali (2013) evaluated biochemical serum factors for fish from the Chahnimeh Reservoirs.

**Conservation.** Listed as of Least Concern by the IUCN (2015).

**Sources.** Type material:- *Schizocypris altidorsalis* (CMNFI 1982-0368, IZA 7841, IZA 7844, IZA 8169 and ZMH 6091) and *Schizocypris brucei* (BM(NH) 1913.4.15:100-109).

Iranian material:- CMNFI 1979-0072, 2, 120.8-162.9 mm standard length, Sistan, river near Zabol (ca. 30º58'N, ca. 61º28'E); CMNFI 1979-0223, 1, 19.9 mm standard length, Sistan, irrigation ditch 1 km south of Lutak (30º45'N, 61º24'E); CMNFI 1979-0224, 13, 48.2-77.5 mm standard length, Sistan, Hirmand River effluent (30º53'30''N, 61º27'E); CMNFI 1979-0225, 1, 147.7 mm standard length, Sistan, Hirmand River effluent (30º58'N, 61º28'E); CMNFI 1979-0226, 107, 60.0-82.5 mm standard length, Sistan, pool near of Kuh-e Khajeh (30º57'N, 61º17'E); CMNFI 1979-0228, 16, 18.1-73.8 mm standard length, Sistan, ditch 1 km from Zabol (31º02'30''N, 61º31'E); CMNFI 1979-0229, 11, 61.0-84.9 mm standard length, Sistan, ditch 5 km from Zabol (31º03'N, 61º33'E); CMNFI 1979-0231, 2, 17.5-19.9 mm standard length, Sistan, jube 3 km from Zabol (31º01'N, 61º32'E); CMNFI 1979-0232, 23, 41.8-78.8 mm standard length, Sistan, ditch 11 km from Zabol (ca. 30º58'30''N, ca. 61º36'E); CMNFI 1979-0233, 2, 66.0-71.5 mm standard length, Sistan, ditch 15 km from Zabol (ca. 30º57'N, ca. 61º38'E); CMNFI 1979-0234, 15, 13.9-82.4 mm standard length, Sistan, effluent of Hirmand River near Zahak (30º54'N, 61º40'E); CMNFI 1979-0235, 4, 148.3-201.9 mm standard length,

Sistan, effluent of Hirmand River (30º54'30"N, 61º41'E); CMNFI 1979-0236, 1, 14.4 mm standard length, Sistan, ditch 27 km from Zabol (ca. 30º52'N, ca. 61º22'E); CMNFI 1979-0237, 5, 21.4-72.1 mm standard length, Sistan, ditch 18 km south of Zabol (30º53'N, 61º27'30"E); CMNFI 2008-0204, 4, 74.3-146.1 mm standard length, Sistan (no other locality data).

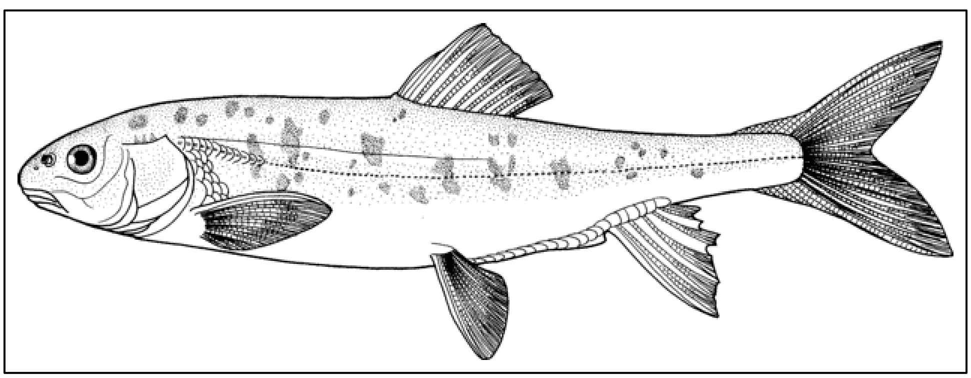
Comparative material:- CMNFI 2008-0053, 1, 70.4 mm standard length, Afghanistan, 50 km west of Qandahar (ca. 31°36'N, 65°10'E); USNM 182276, 5, 95.7-153.1 mm standard length, Afghanistan, Arghandab Reservoir (ca. 31º51'N, 65º55'E); USNM 182277, 1, 159.7 mm standard length, Afghanistan, Arghandab River at Kandahar (ca. 31º35'N, 65º45'E); USNM 182281, 3, 71.2-79.9 mm standard length, Afghanistan, Lashka-dah, Helmand River (ca. 31º35'N, ca. 64º21'E); USNM 182282, 5, 142.1-159.4 mm standard length, Afghanistan, Laskha-dah area (ca. 31º35'N, ca. 64º21'E); ZMUC 261629-34, 6, 131.4-203.7 mm standard length, Afghanistan, Sistan, Feyzabad (31º28'N, 61º31'E).

## Genus *Schizopygopsis*
Steindachner, 1866

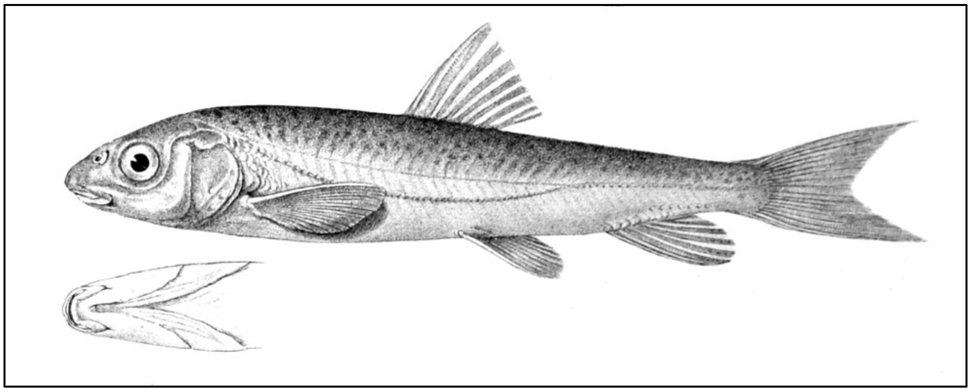
This genus contains about eight species distributed from Iran along the Himalayas to China. There is a single species in Iran.

The osmans are characterised by an elongate and almost cylindrical body, almost scaleless, scales being restricted to the complete lateral line, the flank above the pectoral fin and as enlarged scales around the vent and anal fin base, the mouth is terminal to inferior, the lower jaw is sometimes covered by a horny sheath, lips are present but may only be developed at the mouth corners, no barbels, pharyngeal teeth in two rows, spatulate or cochleariform, short dorsal and anal fins, dorsal fin last unbranched ray thickened (but not strongly) and serrated or denticulate (denticles lost with age), peritoneum black, and gut very elongate.

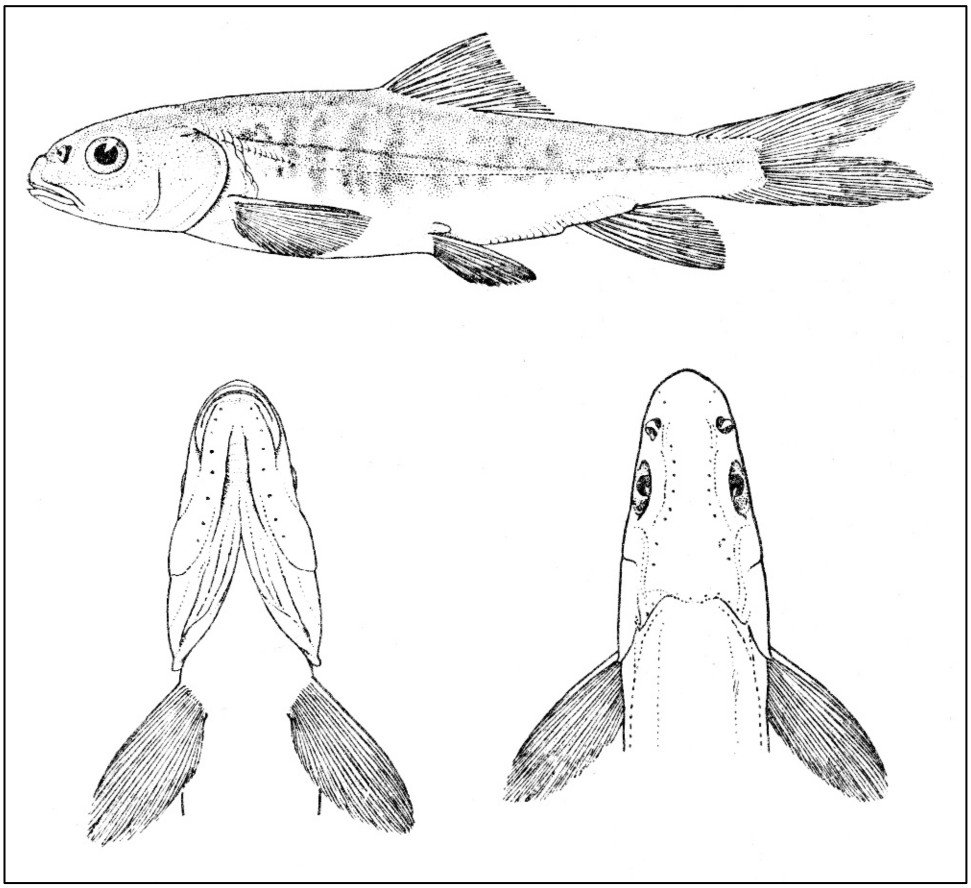
### *Schizopygopsis stolickai*
Steindachner, 1866



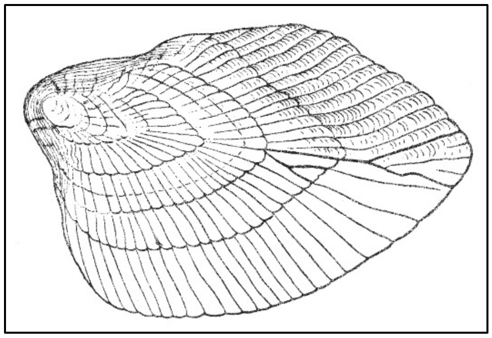
*Schizopygopsis stolickai*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Schizopygopsis stolickai*, after Day (1875-1878).



*Schizopygopsis stolickai*, after Annandale and Hora (1920).



*Schizopygopsis stolickai* anal scale,
after Annandale and Hora (1920).

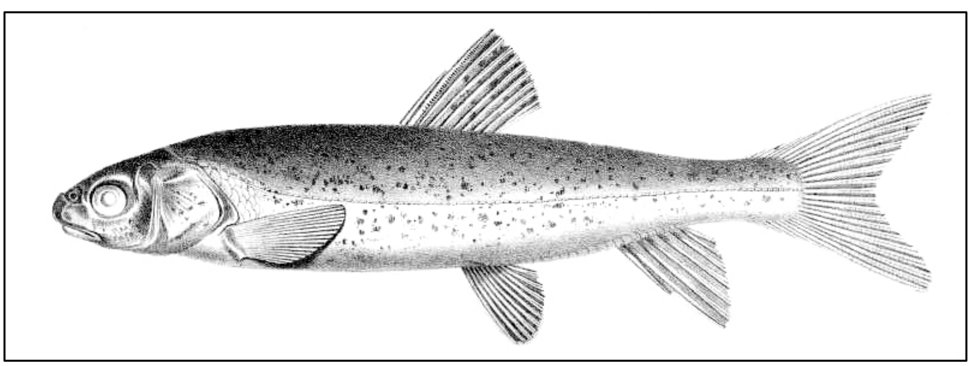
*Schizopygopsis stolickai*, Afghanistan, Pamir, Stephane Ostrowski.

**Common names.** Kopur-e barfi or kapur-e barfi (= snow carp), mahi-ye Zaboli (= Zabol fish, from the city).

[Lozhnyi osman or false osman, common marinka, Pamir osman and Pamir snowcarp in Russian; Kinnaur snowtrout or pamiri in Pakistan].

**Systematics.** The type locality of this species is a stream near Hanle Monastery, Ladakh, India. Syntypes are in the Naturhistorisches Museum Wien under NMW 9255 (1), NMW 9256 (1), NMW 51472 (9) and NMW 51473 (2) (Eschmeyer *et al*., 1996, 1997 Vienna card catalogue).

The species name is spelt *Stoličkai* by Steindachner (1866) which becomes correctly *stolickai* since accents are not used in Latin nor capitals for the scientific species name. It is often spelt *stoliczkae* or *stoliczkai* in the general literature.



*Schizopygopsis stolickai*, syntype, after Steindachner (1866).

*Schizopygopsis sewerzowi* Herzenstein, 1891, originally described from the Bulun Kul and Karasu, in the Amu Darya basin in the Pamir Mountains, occurs together with *S. stolickai*

in the upper Amu Darya. This taxon was used to characterise the form in the Sistan basin of Iran as an infraspecies (Berg, 1948-1949). However, Annandale and Hora (1920) reported both this form and the *stolickai* form, without intermediates, in Sistan. The *sewerzowi* form differs from typical *stolickai* by having a larger eye (1.2-1.3 times in interorbital width as opposed to 1.5-1.7 times and 3.8-4.4 times in head length as opposed to 4.8-5.7 times), a spotted rather than monotone body, smaller size (much less than half that of the typical form), somewhat deeper body, and more oblique mouth with apex at the lower eye level. Data presented below under **Food** indicates that this species can be very plastic in its characters so taxonomic designations would require extensive study of both characters and ecology. The Iranian fish are poorly represented by specimens and are referred here simply to the species.

Syntypes of *sewerzowi* are in the Zoological Institute, St. Petersburg under ZISP 8747, 2, 161.3-161.8 mm standard length, Tajikistan, Bulun Kul (37°20'N, 72°26'E); ZISP 8748, 2, 127.4-127.7 mm standard length, Tajikistan, Bulun Kul (as above); ZISP 8749, 2, 131.6-132.6 mm standard length, Tajikistan, Bulun Kul (as above); ZISP 8800, 1, 183.6 mm standard length, Tajikistan, Kara-su, Amu Darya basin (Pamir) (no other locality data); ZISP 8801, 2, 137.1-147.7 mm standard length, Tajikistan, Kara-su, Amu Darya basin (Pamir) (no other locality data).

Kähsbauer (1964) reported a hybrid between *Schizothorax schumacheri* and *Schizopygopsis stolickai* from Sistan that may in fact be *Schizocypris altidorsalis*.

**Key characters.** The anal fin base has a sheath of enlarged scales and there are a few scales in the shoulder region and along the lateral line but the body is nearly naked, the anal fin has 5 branched rays, barbels are absent, and pharyngeal teeth are in two rows.

**Morphology.** The body is rounded and fairly elongate, deepest at the dorsal fin origin. The dorsal profile in front of the dorsal fin is convex. The caudal peduncle is compressed and shallow. The head is slightly tapering and the snout is rounded. The mouth is subterminal and almost horizontal. The lower jaw is strong, with a dark brown, horny plate. Lips are thick, the upper lip at the middle or the same size from front to back. The lower lip is thick at the corner. The dorsal fin spine is strong at the base and rapidly tapers to be thin. Denticles are medium to strong, well-developed, and numerous in small fish but absent in some large fish. The dorsal fin margin is slightly emarginate, the fin origin is anterior to the level of the pelvic fin origin and the depressed fin does not reach back to the anal fin origin level. The caudal fin fork is moderate to deep and the lower tip is rounded, the upper tip more pointed. The anal fin is rounded and does, or does not extend back to the caudal fin. The pelvic fin is rounded and almost extends back to the anus. The pectoral fin is rounded and remote from the pelvic fin origin.

Lake and river forms of this species exist and lake forms are heterogeneous in their feeding. Savvaitova *et al*. (1987) examined intraspecific variation in this species in a single Pamir lake, Yashil Kul. Fish feeding on aquatic plants, silt, fish and molluscs differed in gut length, mouth form, eye diameter, length and arrangement of fins, and number of gill rakers. They thought that extreme variants could be reproductively isolated. The paucity of the ichthyofauna, presence of free ecological niches and isolation favoured this trophic and morphological divergence. Savvaitova *et al*. (1989) also studied this species in several Pamir lakes and found that groups from a single water body were closer to one another than to analogous groups from other lakes. It can be expected that fish will vary quite markedly over the range of this species, including between different basins, between different altitudes, and between areas with different ichthyofaunas.

Dorsal fin unbranched rays 2-4, branched rays 7-9, usually 8, anal fin unbranched rays 2-3, branched rays 5-7, usually 5, pectoral fin branched rays 11-20, and pelvic fin branched rays 6-10. Lateral line scales 96-120 in literature but see below and Jouladeh-Roudbar *et al*. (2020) gave 29-40 which is incorrect. The lateral line is complete, a pelvic axillary scale is present and the anus and anal fin base are sheathed in enlarged scales. Scales are also present on the anterior lateral line and between there and the anterior pectoral fin base. A double row of scales extends forward from the anal sheath to the pelvic fin bases. The pharyngeal teeth are 3,4-4,3 and have a rounded base becoming spatulate distally with a rounded, hooked tip. Some teeth have a weak, flat cusp with a bump posteriorly below a rounded tip. The gut is very elongate and coiled. Intestinal length varies with trophic group. Predators have a much shorter gut than detritivores, and benthic feeders are intermediate (Savvaitova *et al*., 1989). Total vertebrae number 43-50 (presumably some counts excluded the four Weberian vertebrae and/or the hypural plate; and Jouladeh-Roudbar *et al*. (2020) gave 31-38 which appears to be incorrect).

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(3), anal fin branched rays 5(3), pectoral fin branched rays 17(1), 18(1) or 19(1), pelvic fin branched rays 9(3), lateral line scales 91(1) or 92(1), total gill rakers 11(3), reaching the raker below when appressed, and total vertebrae 48(1) or 50(2).

**Sexual dimorphism.** Tubercles are present on the anal fin of two male specimens, 113.0-116.5 mm standard length, from Sistan in a single file on the last unbranched and first three branched rays. They number up to eight and are often widely spaced. Tubercles are found low on the flank above the anal fin and anus and on the upper flank behind the dorsal fin level. They also line the posterior lateral line. There are also a very few tubercles on the top of the head, side of the snout, below the eye and on the operculum, widely scattered and small (BM(NH) 1905.4.7:1-2). Tubercles are similar on fish from the Zorqul Lake, Afghanistan caught on 4 July 1977 and 159.5 mm standard length and are also be found on the dorsal fin rays (CMNFI 2007-0160).

**Colour.** Dark or yellowish with small dark brown or blackish spots extending onto the fins, or olive with large grey or black spots or blotches, variably few or numerous, or overall bluish-grey, or with a dark upper flank abruptly divided from a light lower flank and belly without any spots or blotches. Spots can be so numerous as to give the appearance of an overall blackish colour. Tilak (1987), however, stated that blackish spots are absent in both old and freshly preserved material. Both spotted and non-spotted forms occur in Sistan. The belly is whitish. Fins are pink. Young fish are finely spotted with melanophores on the flank but are without melanophores on the lower flank and belly. The ventral extent of melanophores increases with size of the fish. The peritoneum is dark brown to black. Different trophic forms in Pamir lakes have different colour patterns, herbivores, detritivores and benthic feeders being dark or yellowish with small spots or olive-coloured with large greyish spots, and predators bluish-grey and bright (Savvaitova *et al*., 1989).

**Size.** Reaches 94.2 cm and 8.6 kg (Solijonov, 2007) but the Sistan form is only up to 22.0 cm and was regarded as a dwarf form by Annandale and Hora (1920).

**Distribution.** This species is found in the mountainous areas of Afghanistan, Pakistan, India and western China. In Iran, restricted to the lowland Sistan basin where reported from the Hirmand River delta and 8 (= 12.9 km) miles east of Lab-e Baring (Annandale, 1921; Vijayalakshmanan, 1950).

**Zoogeography.** The presence of this species in Sistan is an example of a riverine

highway enabling species usually found at higher altitudes to penetrate into lowlands. See also under the genus *Schizothorax*.

**Habitat.** This species is found in Sistan in Iran, presumably in river and marsh habitats. Outside Iran the adults favoured the main river while young were found in shallow streams and pools. In Pakistan, this species preferred high altitudes, high turbidities, high alkalinity, low water temperatures and rivers with rocky and gravelly beds (Rafique, 2007).

**Age and growth.** Savvaitova *et al*. (1989) cited a life span up to 22 years. Age at maturity was 6 years. Maturity in the Sistan form was attained at 18.0 cm. Berg (1949) reported a male fish 14.0 cm long with fairly well-developed testes and tubercles on the anal fin which bears out the dwarf nature of the Sistan fish.

**Food.** Savvaitova *et al*. (1989) examined feeding in certain lakes of the Pamirs at altitudes over 3,220 m. This is much higher than the Sistan populations and the data may not be relevant. However, this is a poorly studied species so such information is a basis for comparison and future research. It is a very plastic species and can adapt to a variety of conditions. This species in the Pamirs was divisible into four groups:- herbivores, detritivores, molluscivores and predators, reflected in the structure of the gut and its length, the number of gill rakers, eye diameter, length and position of fins, and the shape of the horny plate on the lower jaw. Food elsewhere included higher aquatic plants, aquatic insects, diatoms and blue-green algae (see also Akhrorov and Kondur (1981) for species lists of these latter dietary items), detritus, molluscs and fish. In herbivores consuming periphyton, the horny plate on the lower jaw was rasp-shaped with the pointed end aimed anteriorly. In detritivores, the plate was sharper, and in predators, it was larger with the pointed edge directed upwards to grasp prey. Predatory behaviour only developed in fish over 30.0 cm, until which they ate plants. Komarova *et al*. (2021) also examined trophic resource partitioning of ecomorphs in Lake Yashilkul, located at >3,700 m in the Tajikistan Pamir. Four ecomorphs were found, namely detritivorous, predator, benthivorous and phytophagous, but not the molluscivores of Savvaitova *et al*. (1989). The benthivorous ecomorph with a small proportion of molluscs in its diet was defined instead. Food items overall were macrophytes, algae, detritus, invertebrates (Insecta, Arachnida, Crustacea, Bivalvia and Gastropoda), and vertebrates (fish). The predator ecomorph had a shorter gut and was the most enriched in $\delta^{15}N$ (14.5‰), indicating its occupation of the highest trophic level. The lowest $\delta^{15}N$ values (11.1‰) were detected in the detritivorous ecomorph. This sympatric diversification is a very recent process that started ca. 800 years ago after an earthquake caused the damming of the Gunt (Alichur) River, which led to the formation of Lake Yashilkul.

Chaudhary *et al*. (1991) indicated that in a Pakistani population, gut length increased with age and diet changed gradually from an omnivorous to an herbivorous one.

**Reproduction.** Spawning occurred generally from early March to early August at temperatures of 11.2-15.6°C. Spring mouths were favoured in lake forms over sand and sand-pebble substrates. Eggs were large at 2.0 mm diameter (or to 2.1 mm). Spawning was probably non-annual and eggs were shed in one batch (Maksunov, 1971; Savvaitova *et al*., 1987). Relative fecundity was 41.3 eggs/g.

**Parasites and predators.** None reported from Iran.

**Economic importance.** None.

**Experimental studies.** None.

**Conservation.** This species is rarely collected in Sistan and may require conservation measures.

**Sources.** Iranian material:- BM(NH) 1905.4.7:1-2, 2, 113.0-116.5 mm standard length, Sistan (no other locality data); ZISP 25854, 1, 111.5 mm standard length, Sistan (no other locality data).

Comparative material:- BM(NH) 1843.2.25:1-3, 3 skins, 181.0-258.3 mm standard length, Afghanistan, Helmand; BM(NH) 1889.2.1:4381, 1 skin, ca. 322.6 mm standard length, Afghanistan, Sirikol (= Sir-i-Kol, Sari Qul, Zorkul or Victoria Lake, source of the Oxus or Amu Darya) (ca. 37°25'N, 73°42'E); BM(NH) 1931.10.26:2-4, 2, 85.5-138.6 mm standard length, India, Ladakh, stream into Pangong Lake (no other locality data); CMNFI 2007-0157, 4, 25.6-34.7 mm standard length, Afghanistan, Shaur, adjacent to Pamir River (37°24'45.29"N, 73°30'18.07"E); CMNFI 2007-0158, 2, 45.2-53.8 mm standard length, Afghanistan, Gormatek, adjacent to Pamir River (37°19'47.21"N, 73°05'59.57"E); CMNFI 2007-0159, 8, 50.5-119.9 mm standard length, Afghanistan, Qarchin, Pamir River (37°17'56.00"N, 72°59'21.95"E); CMNFI 2007-0160, 3, 69.4-159.5 mm standard length, Afghanistan, rivulets into Zorkul Lake (= Sari Qul, 37°25'22.30"N, 73°38'26.52"E); CMNFI 2007-0161, 4, 45.0-49.3 mm standard length, Afghanistan, Goz Khun, Pamir River (37°01'48.07"N, 72°40'44.54"E); CMNFI 2007-0162, 3, 113.4-123.4, mm standard length, Afghanistan, Goz Khun, Pamir River (37°01'38.46"N, 72°40'46.52"E); CMNFI 2008-0048, 53, 65.3-262.7 mm standard length, Afghanistan, Darya-e Tahelab, Lake Chaqmaqtin (ca. 37°14'N, 74°11'E).

## Genus *Schizothorax*
Heckel, 1838

The snow trouts, snow barbs, snow carps, mountain barbels or Indian trouts are found from Iran to China, favouring mountainous areas but occasionally found in lowlands. There are about 62 species (more if some other genera are included), with three in Iran.

The genera *Racoma* McClelland and Griffith in McClelland, 1842 and *Aspiostoma* Nikol'skii, 1897 are synonyms of *Schizothorax* Heckel, 1838 (Eschmeyer, 1990). *Aspiostoma* is possibly preoccupied by *Aspiostoma* Martens, 1869 in Mollusca (*Catalog of Fishes*, downloaded 29 March 2018).

*Schizothorax intermedius*, and other species, have been placed in the genus *Schizothoraichthys* Misra, 1962 (e.g., in Tilak (1987)). However, *Schizothoraichthys* was regarded as a synonym of *Schizopyge* Heckel, 1847 by Jayaram (1981) or of *Schizothorax* (see Talwar, 1978; Eschmeyer, 1990). *Schizopyge* was itself regarded as a synonym of *Schizothorax* by some authors, e.g., Talwar (1978). Talwar (1978) separated the genus *Oreinus* McClelland, 1838 from *Schizothorax* by the margin of the lower jaw having a firm and hard horny covering which is thickest internally and a thick lower lip with a free posterior edge forming a sucker. *Schizothorax* has a non-suctorial lower lip and a lower labial fold interrupted or entire in the middle. However, Talwar and Jhingran (1991) contradicted this view and used *Schizothoraichthys* for *Schizothorax* and *Schizothorax* for *Oreinus*. Tilak (1987) recognised the name *Schizothorax* for fishes with strip of papillated tissue on the chin and *Oreinus* as a synonym; *Schizothoraichthys* is used then for fishes without the papillated chin. *Oreinus* was regarded as a synonym of *Schizothorax* by Jayaram (1981) and Eschmeyer (1990). Mirza (1991a, 1991b) recognised a tribe Schizothoracini, with the genera *Schizothorax*, *Schizopyge*, *Racoma* (and *Schizocypris*). Kottelat (2013) recognised *Oreinus* as valid and further discussed these generic names while noting that species-level taxonomy should be clarified before reaching taxonomic conclusions at the generic level. I have retained *Schizothorax* here as the

oldest name in view of these conflicting opinions and Kullander *et al*. (1999) had come to a similar conclusion, although they noted that *Oreinus* would have priority over *Schizothorax* based on their interpretation of publication date.

There are various records of nominal *Schizothorax* species from the Helmand River basin in Afghanistan summarised in Coad (1981c, 2014); they have not been reported from the Sistan lowlands of Iran.

This genus is characterised by an elongate and almost cylindrical body, very small scales, over 100 in the series next to the lateral line, scales in complete lateral line somewhat larger, the vent and anal fin base are sheathed in enlarged scales and there may be enlarged scales near the pectoral fin and edge of the gill opening, dorsal and anal fins are short, dorsal fin with a thickened last unbranched ray bearing denticles (denticles lost with age), pharyngeal teeth in three rows and hooked at the tip, four barbels (rostral and maxillary), mouth inferior or subterminal, lower jaw may have a horny sheath, a papillated area on the chin may be present or absent, the lower labial fold may be interrupted or not in the middle, elongate gut and black peritoneum, and poisonous eggs. Members of the Schizothoracinae tribe are of polyploid origin with 2n = 98 and 3n = 148.

Members of this genus may show a great deal of individual variability and species can be quite widely-distributed in areas difficult of access. In addition, some taxa are known only from their original description which often lacks key characters, and some literature records do not have voucher specimens for examination. The possibility of synonymy and misidentification is rife.

The ancestors of the schizothoracines in general were barbinines in the eastern part of the Qinghai-Xizang Plateau as it rose and water temperatures decreased in the late Miocene to early Pliocene (Sizhong, 1995). Primitive genera like *Schizothorax* migrated westwards earlier and further than more specialised genera such as *Schizopygopsis* (although both reach their westernmost distribution in Iran).

These fishes generally prefer rapids and pools of the larger streams at temperatures of 8-22°C although some occur in lakes with inflowing streams (Sharma, 1988). They are found in streams above 3,000 m. Food varies from detritus to insects, plankton and fish depending on the species. The spawning season may be in late summer and early fall or in spring. Egg counts vary from a few hundred to over 50,000 and egg diameters may attain 3.6 mm. Some species show a spawning migration from warm lakes to cold streams.

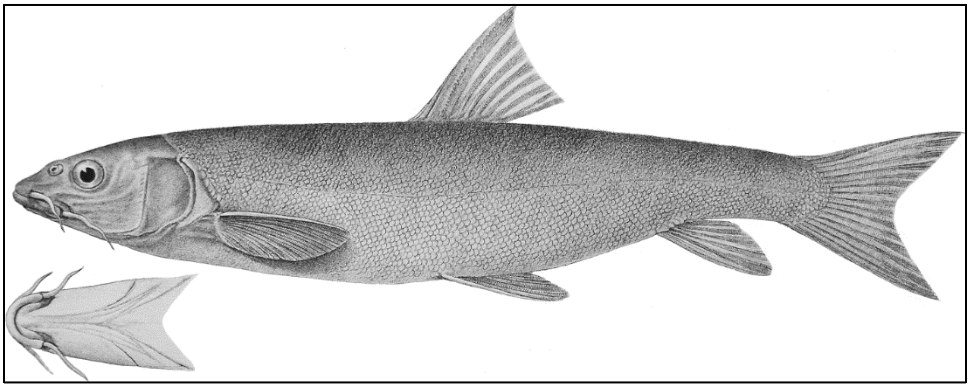
Deaths have occurred from eating poisonous eggs of members of this genus but none are reported from Iran (see under *S. zarudnyi*). Symptoms include abdominal pain, nausea, vomiting, diarrhoea, dizziness, headache, fever, bitter taste, dryness of the mouth, intense thirst, sensation of chest constriction, cold sweats, rapid irregular weak pulse, low blood pressure, cyanosis, pupillary dilatation, syncope, chills, dysphagia and tinnitus. Severe cases show muscular cramps, paralysis, convulsions, coma, and death. Victims generally recover within 3-5 days with supportive treatment but it may take longer. Treatment is symptomatic and there is no known antidote or therapeutic data available. The patient's stomach should be evacuated as soon as possible after ingestion of eggs (Halstead, 1967-1970; Coad 1979). Fish eaten during the breeding season should be cleaned with care to remove all traces of the eggs to avoid contamination of the flesh as cooking does not destroy the toxin.

The following table summarises some key distinguishing characters of the Iranian species of *Schizothorax*.

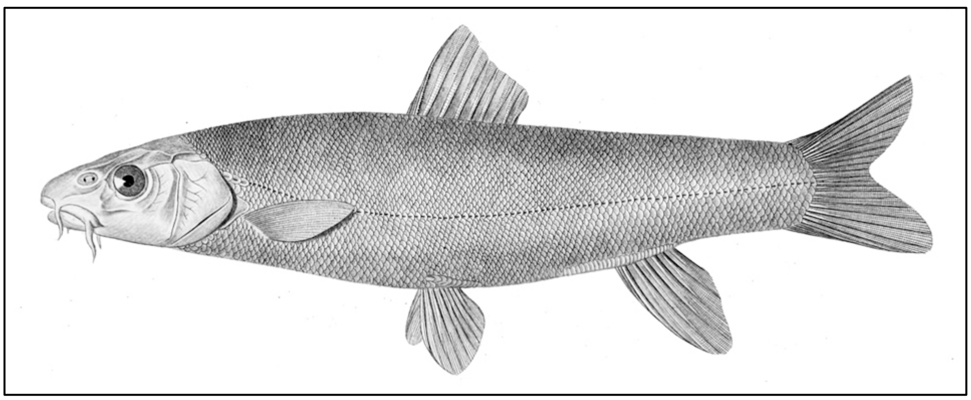
| Species/ | Total gill rakers | Pelvic fin rays | Lateral series scales | Distribution |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Characters | | | (next to lateral line) | |
| *S. intermedius* | 10-19 | 7-10, usually 8 | 115-165 | Sistan |
| *S. pelzami* | 9-18 | 7-9, usually 8 | 155-170 | Hari, Kavir |
| *S. zarudnyi* | 24-41 | 9-10, usually 9 | 190+ | Sistan |

## ***Schizothorax intermedius***
McClelland and Griffith, 1842



*Schizothorax intermedius*, after Day (1875-1878).



*Schizothorax intermedius*, after Kessler (1874b).

**Common names**. Mawda, khajoo and khaju (in Sistan, the latter two also used for other Sistan schizothoracines), shir mahi (= milk fish or sweet fish), marinka (from the Russian).

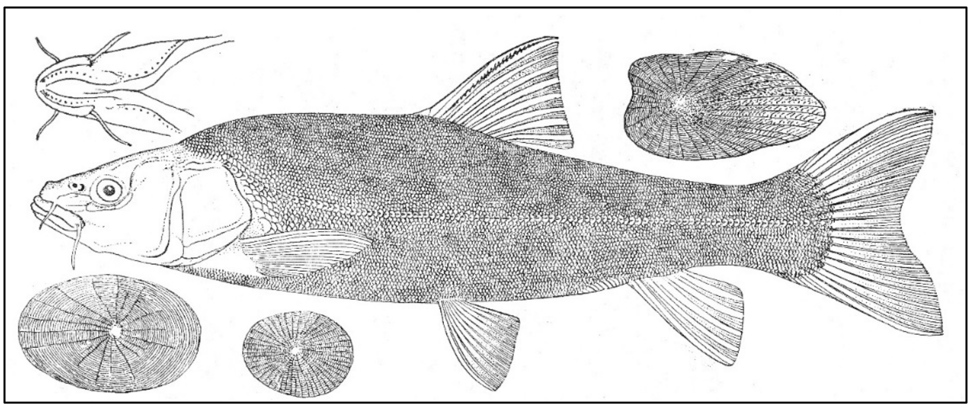
[Marinka obyknovennaya or common marinka in Russian].

**Systematics.** *Schizothorax intermedius* was described from the “Cabul river at Jullalabad. Tarnuck River” in the Indus River basin. No types are known. It could questionably be *S. labiatus* (McClelland, 1842) (originally described from the Kunar River, Afghanistan, see below), or *S. esocinus* Heckel, 1838 according to Kullander *et al*. (1999), or *Schizopyge curvifrons* (Heckel, 1838) according to Menon (1999) (the latter two originally described from Kashmir). It is retained here as a distinct species as opinions differ, it is a wide-ranging taxon requiring detailed study, there is an absence of material available to me, most literature appears under this name, and the fish is found rarely in Sistan and is presumably distinct from other schizothoracines there.

*Oreinus plagiostomus* McClelland, 1842 (not to be confused with *Schizothorax plagiostomus* Heckel, 1838) described from the “Helmund river at Girdun Dewar” in

Afghanistan is a synonym of *S. intermedius*, or possibly a synonym of *Schizothorax curvifrons*. *Racoma brevis* McClelland, 1842 described from the "Helmund River" in Afghanistan is a synonym of *S. intermedius* or possibly *Schizothorax curvifrons*. *Racoma labiatus* McClelland, 1842 described from "Pushut, Koonar river near Jullalabad" in the Indus River basin but also reported from the Helmand River basin by Annandale and Hora (1920) is now recognised as a distinct species in *Schizothorax*. Its presence in the Helmand (= Hirmand) River basin needs confirmation. *Schizothorax ritchieana* McClelland, 1842 described from "Affghanistan. In the Helmund there is a variety of this species .... which will probably prove to be distinct." is a synonym of *S. labiatus*. These taxa have not been identified from Iran and no types are known.

*Schizothorax schumacheri* Fowler and Steinitz, 1956 described from "Zabol, Eastern Iran" is a synonym (Saadati, 1977) of *S. intermedius* (or possibly *S. curvifrons*). The holotype of *Schizothorax schumacheri* (ANSP 71950) at 24.4 cm total length and a paratype (ANSP 71951) at 13.0 cm to the end of the broken caudal fin, are stored in the Academy of Natural Sciences of Philadelphia (Böhlke, 1984).



*Schizothorax schumacheri*, holotype, ANSP 71950,
scales: upper right - large postscapular, lower left - upper lateral predorsal, middle left - preanal,
after Fowler and Steinitz (1956).

Tilak (1987) reported *Schizothorax richardsonii* (Gray, 1832) from Sistan based on two fish in the Zoological Survey of India, Calcutta (F. 1226-1227/1), which I have not seen.

Berg (1948-1949) reviewed three morphae or forms of this species which indicated the great variation in this taxon. He also noted how barbel length varied independently of morpha and how the lips may be very strongly developed. The forms are as follows and were originally described as distinct species and are recognised as such by authors (see *Catalog of Fishes*):- *typica*, *eurystomus* Kessler, 1872 (described originally from Dznam near Samarkand, Uzbekistan with no types extant and recognised as a distinct species by Wu and Wu (1992)) and *fedtschenkoi* Kessler, 1872 (originally described from the Zeravshan River, Uzbekistan). *Eurystomus* has a transverse jaw covered by horny padding and a strong or weak dorsal fin spine. *Fedtschenkoi* has a lower jaw without the horny pad, the lower lip is continuous or interrupted (the form with an interrupted lip is called morpha *irregularis* Day, 1896 (the date is incorrect in Berg (1948-1949) and should be 1877 and this taxon is now recognised as a synonym of *S. curvifrons*), and the dorsal fin spine is weak with 10-22 denticles extending to the mid-point or two-thirds along the ray. The form *typica* has a crescent-shaped lower jaw without horny padding, the dorsal fin spine is well-developed with 12-32 denticles extending distally beyond the mid-point, and the lower lip is interrupted.

Kähsbauer (1964) reported a hybrid between *Schizothorax schumacheri* and *Schizopygopsis stolickai* from Sistan that may in fact be *Schizocypris altidorsalis*.

**Key characters.** Gill raker counts and distribution separate this *Schizothorax* from others in Iran.

**Morphology** This is a very variable species, depending on habitat (see Berg (1948-1949) and Mirzaev (1998) for variation in body shape and comments above and below). There is considerable variation in lower jaw form in specimens attributed to this species. The lower jaw may be crescent-shaped with or without a sharp horny sheath, or covered with a deciduous horny layer, or transverse and covered by a horny sheath. Lips may be interrupted medially or continuous, and can be very strongly developed. The dorsal fin spine may be well-developed with numerous denticles or weakly-developed with denticles not beyond the middle of the spine. Various morpha or infraspecies have been described to refer to these forms (see Berg (1948-1949) and above). Barbel length is highly variable. Young about 30.0 mm long have a naked body and no barbels.

Dorsal fin with 2-4 unbranched and 5-9, usually 8 branched rays (Kullander *et al*. (1999) gave 6-7 rays for their Kashmir specimens of *S. curvifrons,* one reason for retaining *intermedius* as distinct), anal fin with 1-3 unbranched and 4-7, usually 5, branched rays, pectoral fin branched rays 14-19, and pelvic fin branched rays 7-10, usually 8. Lateral line scales 85-122, scale series next to the lateral line 115-165. Gill rakers number 10-19 (Kullander *et al*. (1999) gave 21-28 for their Kashmir specimens of *S. curvifrons,* another reason for retaining *intermedius* as distinct). Pharyngeal teeth are 2,3,5-5,3,2. Total vertebrae number 48 (Howes, 1987) or 40-43 (Mirzaev, 2000a) - the latter presumably excluding four Weberian vertebrae and possibly the last complex vertebra). The chromosome number is 2n = 98-100.

**Sexual dimorphism.** Unknown.

**Colour.** This species is usually silvery and occasionally has minute black spots on the upper half of the body, but is usually without spots. The head is olive-green, the iris orange or bright silvery white, and bases of lower fins are orange. In preservative, a pale greyish-brown above, flanks and lower surfaces brilliant silvery or light yellow. Fins are greyish to pale olive with lower ones whitish.

**Size.** Reaches 60.0 cm (Solijonov, 2007) and 3.0 kg.

**Distribution.** This species is found in the basins of the Indus, the Amu Darya and Syr Darya rivers, the Tarim basin, the Helmand (= Hirmand) and Hari River basins of Afghanistan and Iran. Jouladeh-Roudbar *et al*. (2020) recorded this species from the Hari River basin in the Kalat River.

**Zoogeography.** See under genus description.

**Habitat.** Reported from both lotic and lentic environments but little is known of its environmental requirements. Solijonov (2007), in a study of fishes in the Pamir-Alai Transboundary Conservation Area, found this species as being most active in the evening and so was seldom caught in the daytime when it hid in refuges among rocks. It maintained station in fast water of Pamir-Alai mountain streams behind rocks and in whirlpools. In the Chatkal Biosphere Reserve of Uzbekistan, a mountain area, as reported by Mirzaev (2000a), this species preferred cool waters with rapid but not rough flow over a bottom of stones and pebbles. The fish congregated in shoals in small pits and gullies. It was able to surmount small waterfalls.

**Age and growth.** Life span is at least 8 years. Males mature at 2-3 years and females at

3-4 years and spawning takes place in mid-May.

**Food.** Food is small aquatic fauna, vegetation and detritus. Akhrorov and Kondur (1981) found macrophytes, detritus and molluscs to be important foods in a Pamir lake, varying with the year of sampling such that molluscs dominated in one year and macrophytes in another.

**Reproduction.** Spawning took place between May and September, depending on locality, and 8,678-59,895 eggs were produced in fish 21.5-37.1 cm and 211-913 g (Mitrofanov *et al*., 1988). E. Khurshut (Fishes of Uzbekistan, http://uznix.narod.ru/sci/fkey/fishkey.html, downloaded 23 December 2010) gave a spawning time of April to summer in Uzbekistan, at a temperature range of 9-14°C, over rocky gravel in 0.5-1.5 m depth. Initially adhesive, eggs rolled off under stones to develop. Fecundity reached 80,000 eggs. Spawning was probably non-annual in some areas (Maksunov, 1971).

**Parasites and predators.** None reported from Iran.

**Economic importance.** Eggs of this species are known to be poisonous to humans. It is of local economic importance in Uzbekistan and is caught by sport fishermen (E. Khurshut, Fishes of Uzbekistan, http://uznix.narod.ru/sci/fkey/fishkey.html, downloaded 23 December 2010).

**Experimental studies.** None.

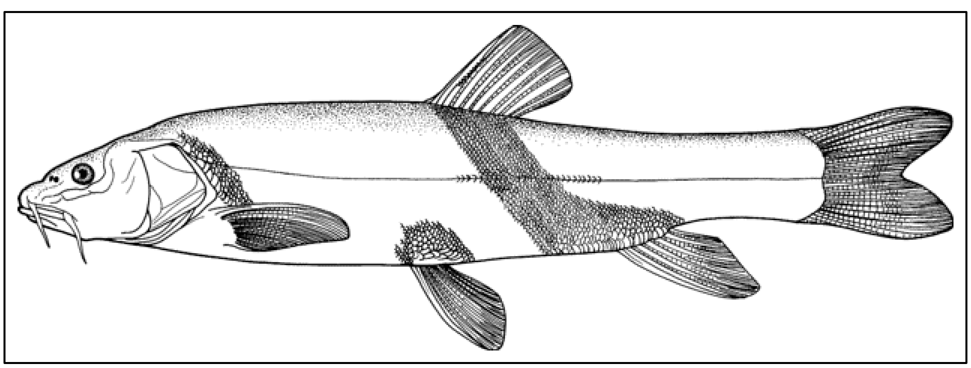
**Conservation.** This species is not well-documented in Iran and no assessment of conversation needs can be made. It may be a stray from higher latitudes in Afghanistan. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern.

**Sources.** Type material:- *Schizothorax schumacheri* (ANSP 71950 and ANSP 71951).

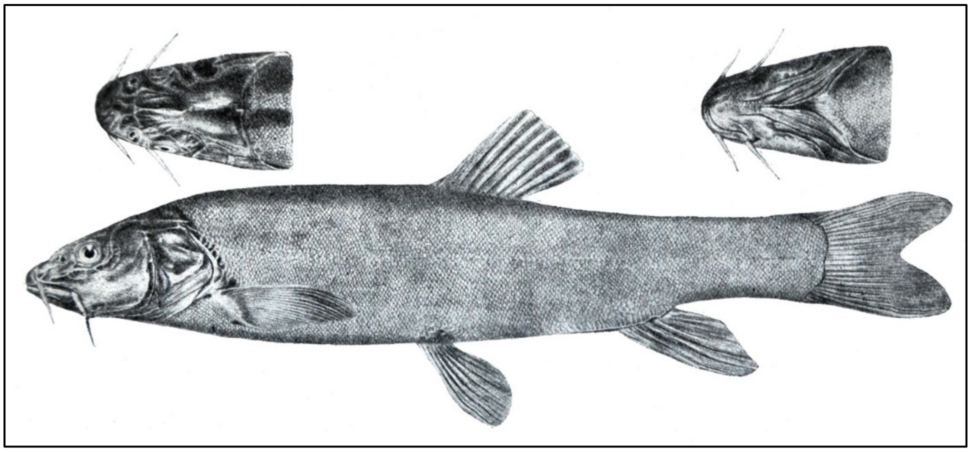
Iranian material:- None (except above).

Comparative material:- CMNFI 2008-0050, 1, 117.2 mm standard length, Afghanistan, Kabul River, Kabul (34°31'N, 69°11'E); CMNFI 2008-0052, 1, 221.4 mm standard length, Afghanistan, Band-e Kajaki (= Kajaki Dam, ca. 32°22'N, 65°11'E); SNM-PM 6814, 2, 96.9-99.8 mm standard length, Afghanistan, brooklets flowing out of Band-e Amir Lakes (no other locality data).

## ***Schizothorax pelzami***
Kessler, 1870



*Schizothorax pelzami*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Schizothorax pelzami*, after Berg (1912).

*Schizothorax pelzami*, Iran, Dasht-e Kavir basin, Hamid Reza Esmaeili.

*Schizothorax pelzami*, Semnan, Cheshmeh Ali Damghan, Asghar Abdoli.

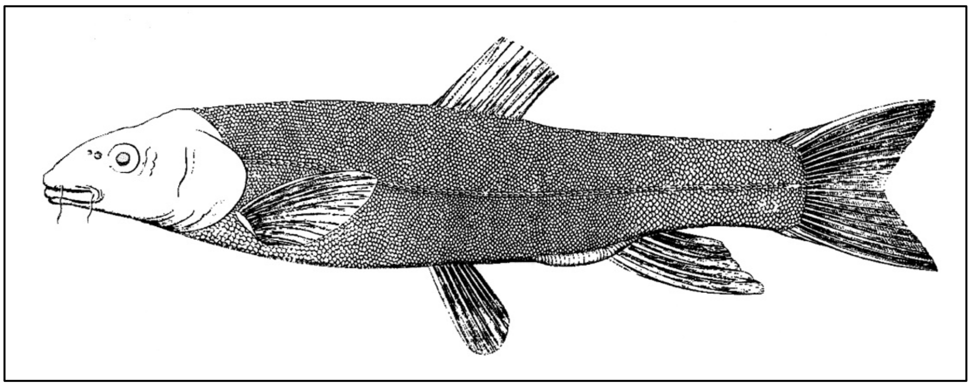
*Schizothorax pelzami*, Semnan, Cheshmeh Ali Damghan, Asghar Abdoli.

**Common names.** Shir mahi (= milk fish), chahu, khajo, khaju and khajoo (presumably after the historic island in Lake Hamun used for *S. zarudnyi* and here as a general term for a snow trout).

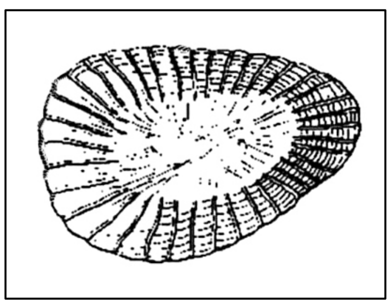
[Zakaspiiskaya marinka or Transcaspian marinka, and forel (incorrectly as this means trout), in Russian].

**Systematics.** *Schizothorax raulinsii* Günther, 1889 described from a skin from the "Hari-rud River, near Khusan" and *Schizothorax pelzami iranicus* Karaman, 1969 are synonyms. Wossughi (1978) considered *Schizothorax pelzami iranicus* to be only a large specimen of *S. p. pelzami* and Coad and Keyzer de Ville (2004) concurred.

The holotype of *Schizothorax Pelzami* is in the Zoological Institute, St. Petersburg (ZISP 8036, 26.5 cm total length) and is from "Fl. Schach-rud. accursus fl. Sefid-rud in Persia. 1889. Univ. Petropol.". The Shah Rud or Shah River is a tributary of the Sefid River of the Caspian Sea basin but this species does not occur there. Berg (1948-1949) cited A. N. Derzhavin who suggested that this Shah-rud is south of Astrabad (= Gorgan). There is a Shahr Now River in the Hari River basin where this species is found (*shahr* is the Farsi for city and may have been a general term for a major river of northeastern Iran as it flows through a city). However, the type probably came from the environs of the city of Shahrud (= Emamshahr) in the Damghan basin, a sub-basin of the Dasht-e Kavir basin (see below).



*Schizothorax pelzami*, holotype, after Kessler (1870).



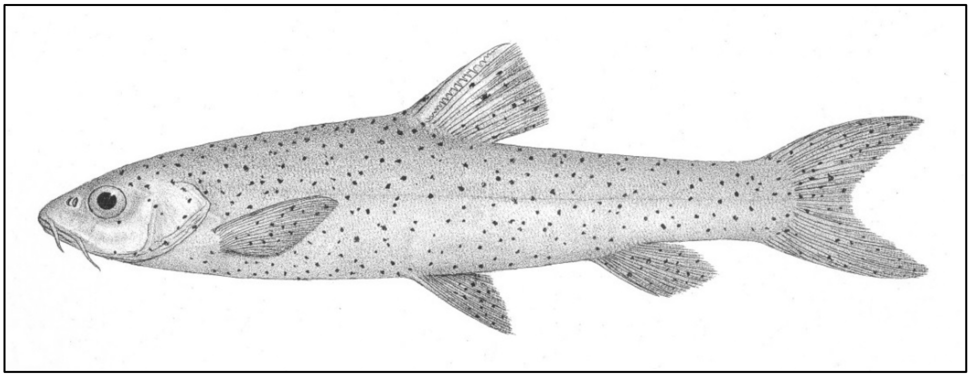
*Schizothorax pelzami*,
flank scale, after Kessler (1870).

Another specimen listed as a type from the "Schah-Roude. Persia. Pelzame. St. Petersburg University" measuring 78.6 mm standard length is in the Natural History Museum, London (BM(NH) 1897.7.5:24). Kessler (1870) and Eschmeyer (1998) listed four syntypes so two appear to be lost but Coad and Keyzer de Ville (2004) pointed out a disparity in size range (12.0-18.0 cm for the syntypes according to Kessler (1870)) while the London fish is too small and may not be a type despite its label.

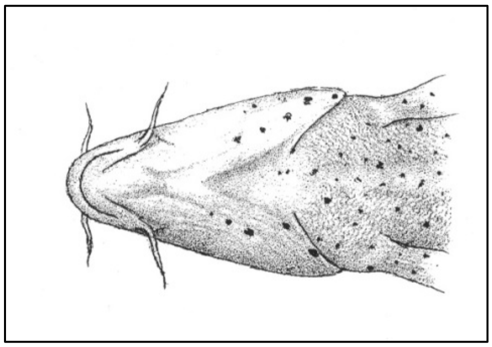

*Schizothorax pelzami*, syntype. BM(NH) 1897.7.5:24.

The type of *Schizothorax raulinsii* is from the Hari-rud River, near Khusan, Afghanistan. BM(NH) 1886.9.21:181 is a skin marked as a syntype, 312.8 mm standard length, presumably the skin referred to by Eschmeyer *et al*. (1996). The skin is also marked *Schizothorax* "*aitchisonii*" (= *S. raulinsii*, a synonym of *S. pelzami*); Albert Günther of the British Museum apparently confused the names Aitchison and Raulins, collectors of specimens on the Afghan Delimitation Commission; *aitchisonii* was never used and the skin is a syntype of *raulinsii*. Eschmeyer listed a skin and two other syntypes in the Natural History Museum, London and two syntypes in the Zoological Survey of India, Calcutta (ZSI F11477-78). These four additional specimens are presumably the four smaller fishes mentioned by Günther (1889) in his original description as being collected at Bezd on the Jam River in Iran. BM(NH) 1886.9.21:171-172, 2, 87.8-100.9 mm standard length, Bezd, were not listed as syntypes in the British Museum, however, when examined by me.

*Schizothorax raulinsii*, holotype, BM(NH) 1886.9.21:181, Brian W. Coad.



*Schizothorax raulinsii*, young, after Günther (1899).



*Schizothorax raulinsii*, ventral head,
after Günther (1899).

*Schizothorax pelzami iranicus* Karaman, 1969 was described from “Teheran in Quelle” (= Tehran in a spring) based on a single specimen. *Schizothorax pelzami* does not occur in the Namak Lake basin in which Tehran lies and the subspecies may have come from the Damghan part of the Dasht-e Kavir basin. The subspecies differs from the type subspecies by having a weakly ossified spiny ray in the dorsal fin (only the first half with small teeth), smaller eyes, longer snout and an overall brown to blackish-grey body colour with all fins, lips and barbels dark-coloured as opposed to the sharp boundary between the dark brown dorsal side and the light ventral side (Karaman, 1969b). The Damghan part of the Dasht-e Kavir basin is the type locality of the taxon and *S. p. iranicus* is a synonym of the type species (Coad and Keyzer de Ville, 2004). The holotype of *S. p. iranicus* is in the Zoologischen Instituts und Zoologischen Museums der Universität Hamburg (ZMH H4116, 327.5 mm standard length).

*Schizothorax pelzami iranicus*, holotype, ZMH H4116, Brian W. Coad.

Starostin (1936) reported a hybrid of this species and *Capoeta heratensis* from Turkmenistan.

Khazaee *et al*. (2014) found the genus *Schizothorax* was monophyletic and found two clades of *S. pelzami* based on the mitochondrial gene *COI*. Sazgar *et al*. (2017) found populations from the Roein Fountains (*sic*, presumably springs) and at Abghad and Karde were morphometrically isolated from others while Kavir and Tedzhen or Hari River populations were not completely distinct.

Sazgar *et al*. (2019) measured 124 fish from the Tajan (= Tedzhen or Hari River) and Kavir basins using 17 landmarks. Differences were related to the snout region, the head depth, and in the chest and thoracic positions, indicating the flexibility of these parts in response to environmental conditions of the habitats.

Mouludi-Saleh *et al*. (2020) examined morphometrically 81 specimens from the Aal, Bidvaz, Cheshmeh Ali and Kalat rivers of the Hari River and Dasht-e Kavir basins (see **Distribution**) and found the main differences were related to the position of the snout, the depth of the head and body, and the length of caudal peduncle. These were considered to be an adaptation to their habitat, which has been influenced by different environmental parameters.

**Key characters.** This is the only schizothoracine species in northeast Iran and is easily recognised by its high lateral line scale count and the enlarged scales around the anus and anal fin.

**Morphology.** The body is rounded and deepest between the pectoral and pelvic fin bases. The dorsal profile is convex to almost straight in front of the dorsal fin. The caudal peduncle is compressed and moderately deep. The mouth is inferior. A groove over the snout anterior to the nostrils is present in some fish. The lower lip is interrupted medially and is expanded at the mouth corners. The upper lip is thick. Mouth shape varies from a u-shape to a sector mouth (a gentle arch) or is almost straight, the latter two shapes with a horny edge. The lower jaw horny sheath may be lacking. Berg (1948-1949) called the form with a horny sheath morpha *oreiniformis*. The snout is rounded and the rostral flap does not cover the upper lip. The anterior barbels extend back to the anterior eye margin or the mid-eye while the posterior barbels extend to the rear eye margin or beyond. Barbel size is variable and not obviously related to size although smaller fish tend to have proportionately longer barbels. The anterior barbels are slender, the posterior ones thicker but tapering. The dorsal fin spine is moderate to very strong and thick with well-developed and widely-spaced denticles, almost reaching the tip or to about three-quarters of the spine length. The dorsal fin margin is straight to slightly emarginate. The dorsal fin origin is posterior to, or over, the level of the pelvic fin origin and

when appressed does not reach back to the anal fin origin level. The caudal fin is very slightly emarginate or moderately forked and has rounded to pointed tips.The tip of the anal fin reaches back beyond the middle of the caudal peduncle. The anal, pelvic and pectoral fin margins are rounded. The pectoral fin does not reach back to the pelvic fins and the pelvic fins do not approach the anal fin origin but almost to the naked keel or groove.

Dorsal fin unbranched rays 3-4, branched rays 7-8, anal fin unbranched rays 3, branched rays 5-6, usually 5, pectoral fin branched rays 16-21, and pelvic fin branched rays 7-9. Lateral line scales 84-108, lateral series scales 155-170, about 32 between the dorsal fin spine and the lateral line and about 27 between the lateral line and pelvic fin. The anal papilla and anal fin lie in a groove formed by enlarged scales, the groove extending about one third to half way between the anal fin origin and pelvic base. Enlarged scales are found behind the operculum on the flank and along the lateral line. The belly is scaled up to the isthmus. There is a scaled pelvic axillary process. Scales are oval and obliquely inserted into scale pockets on mid-flank, sloping backwards postero-dorsally. The focus is subcentral anterior and radii are present on all fields. Circuli are few in these small scales. Total gill rakers number 9-18, relatively short and reaching the adjacent raker or slightly beyond when appressed. Occasional rakers are forked. Pharyngeal teeth are usually 2,3,5-5,3,2, with variants 2,3,4-5,3,2, 2,3,5-4,3,2, 2,2,5-5,3,2 and 1,3,5-5,3,2. Teeth are rounded with an evident hooked tip and posterior teeth have a short to medium flat grinding surface below the tip. Teeth may also be spatulate or have a spatulate shape with the hollow filled in. The gut is very elongate and coiled. Total vertebrae number 43-49.

Jalili *et al*. (2019) described the osteology of this species from fish in the Dasht-e Kavir basin.

Meristic values for Iranian specimens are:- dorsal fin branched rays 7(11) or 8(22), anal fin branched rays 5(33), pectoral fin branched rays 16(2), 17(4), 18(12), 19(6), 20(8) or 21(1), pelvic fin branched rays 7(2), 8(30) or 9(1), lateral line scales 85(2), 86(2), 87(-), 88(2), 89(1), 90(2), 91(2), 92(2), 93(2), 94(-), 95(2) …., 98(2), 99(7), 100(3), 101(-), 102(1), 103(-), 104(1), 105(1) …. or 108(1), total gill rakers 9(1), 10(5), 11(6), 12(7), 13(8), 14(1), 15(2), 16(1), 17(1) or 18(1), pharyngeal teeth 2,3,5-5,3,2(15), 2,3,4-5,3,2(2), 2,3,5-4,3,2(1), 2,2,5-5,3,2(1) or 1,3,5-5,3,2(1), and total vertebrae 43(6), 44(10), 45(1), 46(2), 47(2), 48(-) or 49(1).

**Sexual dimorphism.** A male specimen, 123.9 mm standard length, caught on 6 April (CMNFI 1993-0124A) had small to moderate-sized tubercles on the top and sides of the head but these were not fully developed. The largest tubercles were found between the nostrils and the upper lip on the snout. No tubercles were noted on the fins. Fish taken on 5 November 1974 (CMNFI 2007-0003) also had small but distinctive tubercles.

**Colour.** The overall colouration is silvery usually without any pattern but the back and upper flank are blackish to olive or brassy and the belly is whitish in small fish to a strong yellow in large fish. The back may be iridescent blue-green. The upper and mid-flank may be spotted and blotched. The lateral line may be lighter than the surrounding flank, appearing as a thin, whitish line, or darker than the adjacent flank. The lips, pectoral, pelvic and anal fins are yellow. Fin bases are bright orange, the gill slit has a bright orange streak and the isthmus is bright orange. All fins may be flushed with red in freshly caught material and the lower flank and belly can have pinkish tinges. The dorsal fin base may be dark. The iris is red dorsally. The peritoneum is a dark brown.

Preserved fish have a uniform brown colour with faint to dark speckles arranged irregularly on the flank. There are no obvious patterns on the fins although they are darkened

by melanophores on both rays and membranes.

Günther (1889) reported the caudal fin as black, but this is possibly a dried or otherwise abnormal specimen. The colouration of the *iranicus* nominal subspecies in the original description (cited above) is not borne out by specimens from Damghan, the presumed locality of the type specimen, and again may be an artefact of preservation or simply a variation.

**Size.** Attains 54.0 cm (Muhomedieva, 1967) and reputedly 3.0 kg in qanat specimens (R. J. Behnke, *in litt*., 1981).

**Distribution.** This species is found in the Dasht-e Kavir basin in Iran and the Tedzhen and Murgab rivers of Afghanistan and Turkmenistan including Iranian drainages of the former known as the Hari River in its Iranian reach (Aliev *et al*., 1988). It is recorded from the Astaneh, Bidoaz or Bidvaz, Jajarm, Joveyn and Kal-e Shur rivers in the Dasht-e Kavir basin, as well as Cheshmeh Ali at Damghan and Cheshmeh Badash near Shahrud further west; and in the Aal, Akhland, Farizi (or Frizi), Golmakan, Hari, Jam, Kalat, Kardeh, Kashaf, Laiinsoo, Ros and Sharak rivers, Cheshmeh Sabz Lake, the Kardeh Dam and various smaller water bodies in Razavi Khorasan in the Hari River basin, and in the Roein Fountains (*sic*, presumably springs) and at Abghad and Karde (all presumably in Razavi Khorasan) (Günther, 1889; Nikol'skii, 1897, 1899; Abdoli, 2000; Coad and Abdoli, 2000; Abdoli *et al*., 2007; Soltani *et al*., 2011; Bagheri Dorbadam *et al*., 2013; Badri *et al*., 2015; Abbasi *et al*., 2016; Sazgar *et al*., 2017; Badri *et al*., 2019; Mouludi-Saleh and Eagderi, 2019).

Wossughi (1978) recorded this species from the Hamun-See (= Sistan) but this is an error.

**Zoogeography.** Saadati (1977) found slight differences between fish from the Dasht-e Kavir basin and from the Hari River basin, in raker counts and caudal peduncle depth. He concluded that isolation in the Dasht-e Kavir basin is relatively recent and migration has occurred westwards in the past 15-25,000 years. The occurrence of this species in the western Dasht-e Kavir basin (the Damghan basin) is the westernmost distribution of the schizothoracine fishes. See also under the genus *Schizothorax*.

**Habitat.** This species is found in rivers, streams, lakes, dams, springs and qanats but environmental requirements are mostly unknown. Collection data included a temperature of 16ºC, pH 7.2, river width 20-100 m, medium current, detritus, sand, stone or boulder bottoms, submergent vegetation, and a forested shore.

Habitat of *Schizothorax pelzami*, Semnan, Cheshmeh Ali Damghan, Asghar Abdoli.

Habitat of *Schizothorax pelzami*, Semnan, Cheshmeh Ali Damghan stream, Asghar Abdoli.

**Age and growth.** Life span exceeded 7 years in Turkmenistan (Muhomedieva, 1967). Abdoli *et al*. (2007) found males reached 23.3 cm and 145.6 g and females 34.0 cm and 428 g in the Laiinsoo River. The male:female sex ratio was 2.5:1. Bagheri Dorbadam *et al*. (2013) found fish from the Sharak River in Razavi Khorasan Province up to 31.4 cm and 314.3 g.

Badri *et al*. (2015) examined 873 fish from the Farizi River basin and Cheshmeh Sabz Lake in Razavi Khorasan finding that the lake population was heavier and larger than the river population, presumably because of better environmental conditions and food supply. The *b* values were positively isometric in river females (3.102) and lake males (3.107) and negatively allometric in river males (2.807) and lake females (2.828). Badri *et al*. (2019)

examined the opercular bones of 261 fish from the Frizi (or Farizi) River and 234 fish from the Cheshmeh Sabz Lake ranging in length from 6.9 to 27.4 cm total length. The instantaneous growth rate of young (one and two-year-old) fish in the river habitat (with a higher mean temperature) was higher than the population living in the lake habitat (with a lower mean temperature). Fish lived longer in the lake habitat. Almost all reached maturity at 2-3 years old in the river site but at age 4 and 5 years old in the lake site. von Bertalanffy growth parameters showed that $L_\infty$ in the lake population (♂464.66, ♀514.70) was higher than river population (♂303.15, ♀ 456.92). Growth performance index (φ') was calculated in the lake habitat as 9.386 in females and 9.225 in males and in the river habitat as 9.253 and 9.074 respectively. Males outnumbered females in the river habitat and vice versa in the lake habitat. Differences in habitat conditions, especially water temperature, led to the formation of different strategies in age structure and pattern of growth in each population.

Abbasi *et al*. (2019) gave a *b* value of 3.05 for 54 fish, 4.4-27.1 cm total length, from the Kardeh River. Mouludi-Saleh and Eagderi (2019) found a *b* value of 2.87 from five fish, 9.08-14.48 cm total length, from the Aal River in the Hari River basin.

**Food.** The diet was 93-99% fishes including *Cyprinus carpio* according to Muhomedieva (1967). Other foods included small *Capoeta capoeta* (= *C. heratensis*), chironomids, caddis flies, dragonflies, other aquatic insects, and plant material in Turkmenistan (Aliev *et al*., 1988). Crustaceans, plant fragments and filamentous algae, and possibly fish eggs, may also be found in gut contents. Abdoli (2000) listed Plecoptera, Ceratopogonidae, Trichoptera, Ephemeroptera, Chironomidae and Simuliidae for Iranian fish. Abdoli *et al*. (2007) found fish in the Laiinsoo River had a diet dominated by chironomid pupae and simuliid larvae, with nine other benthic invertebrate food items taken.

**Reproduction.** Egg diameter reached 2.0 mm and numbers reached 36,300 eggs (Aliev *et al*., 1988). An Iranian fish collected on 6 April 1993 (CMNFI 1993-124A) had developing eggs suggesting a spring or early summer spawning period. Bagheri Dorbadam *et al*. (2013) examined fish from the Sharak River near Quchan which had a male:female sex ratio of 1:1.45, the maximum gonadosomatic index was 10.14 in April for males and 10.41 in June for females, egg diameter reached 1.96 mm, absolute fecundity was 2,158-7,638 eggs, and relative fecundity was 40-292 eggs/g. Safari *et al*. (2014) found the maximum gonadosomatic index and egg diameter were in April, and there was a single-spawning strategy with best spawning time in March to April at 15.7-17.3ºC. Berg (1948-1949) noted fluid sexual products in both sexes caught in July in the Germab (river) (Geok Tepe, Turkmenistan) suggesting spawning may occur over extended periods or vary between localities.

**Parasites and predators.** Barzegar *et al*. (2008) recorded the digenean eye parasite *Diplostomum spathaceum* from this fish from the Hamun Lake, Sistan. Tavakol *et al*. (2015) reviewed the acanthocephalan fauna of Iran and noted *Pallisentis* sp. from fish in the Hamun Lake. Both these records are misidentification of the fish species or locality confusion.

**Economic importance.** None.

**Experimental studies.** Ebrahimi *et al*. (2017) found juveniles have diurnal locomotor and feeding rhythms in this candidate species for aquaculture. Ebrahimi *et al*. (2020) determined the chemical composition and amino acid profile of carcasses and the level of activity of the digestive enzymes, finding an omnivorous eating habit which tended to carnivory. The data on the chemical composition and amino acid profile could be applied as a template for formulation of dietary foods.

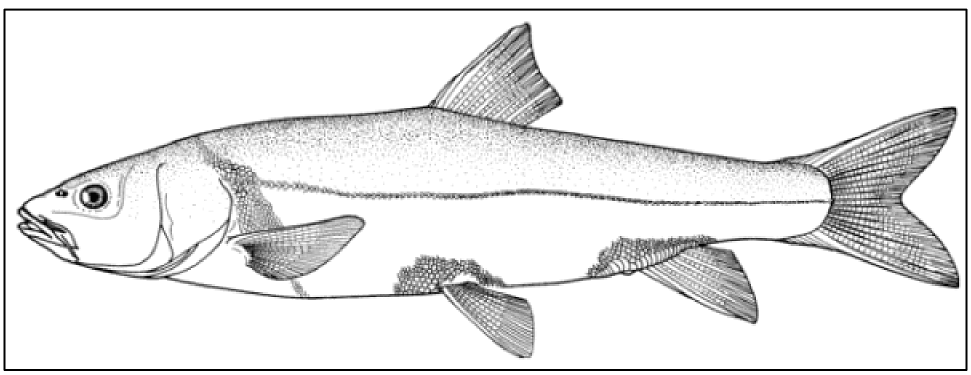
**Conservation.** Listed as of Least Concern by the IUCN (2015).

**Sources.** Type material:- *Schizothorax pelzami* (ZISP 8036 and possibly BM(NH) 1897.7.5:24), *Schizothorax pelzami iranicus* (ZMH 4116) and *Schizothorax raulinsii* (BM(NH) 1886.9.21:181).

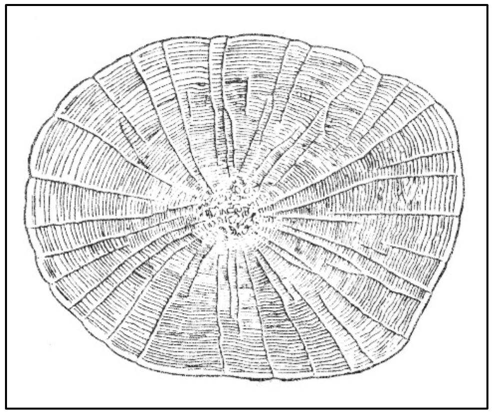
Iranian material:- CMNFI 1993-0124A, 1, 123.9 mm standard length, Semnan, Cheshmeh Ali-Damghan (36º17'N, 54º05'E); CMNFI 2007-0003, 8, 97.6-189.5 mm standard length, Semnan, Cheshmeh Ali (ca. 36º17'N, ca. 54º46'E); CMNFI 2007-0004, 6, 75.6-109.5 mm standard length, Semnan, Cheshmeh Bedasht (ca. 36º35'N, ca. 55º03'E); CMNFI 2007-0012, 2, 77.8-127.6 mm standard length, Razavi Khorasan, qanat at Bagh-e Jan (ca. 36º00'N, 58º38'E); CMNFI 2007-0013, 2, 55.9-80.4 mm standard length, Razavi Khorasan, qanat 5 km north of Boghai (ca. 36º02'N, ca. 59º31'E); CMNFI 2007-0014, 3, 88.7-98.1 mm standard length, Razavi Khorasan, Kuh-e Sang Park, Mashhad (ca. 36º18'N, ca. 59º36'E); CMNFI 2008-0229, 4, 27.6-49.5, mm standard length, Semnan, qanat at Shahrud (no other locality data); BM(NH) 1914.1.1:16-17, 2, 98.0-163.9 mm standard length, Razavi Khorasan, Kashaf River, Mashhad (no other locality data); BM(NH) 1914.1.1:18-20, 3, 138.5-242.0 mm standard length, Razavi Khorasan, small stream near Mashhad (no other locality data); BM(NH) 1914.1.1:21-23, 2, 151.2-165.7 mm standard length, Khorasan, Cheshmeh-e Saby (no other locality data); BM(NH) 1914.1.1:24-29, 5, 147.6-188.8 mm standard length, Razavi Khorasan, Langar, Jam River (35º23'N, ca. 60º25'E).

Comparative material:- BM(NH) 1886.9.21:173-175, 3, 115.8-129.2 mm standard length, Afghanistan, Kushk (= Koshk-e Kohneh, ca. 34°52'N, 62°31'E); BM(NH) 1886.9.21:182, skin, 274.0 mm standard length, Afghanistan, Kushk (= Koshk-e Kohneh, ca. 34°52'N, 62°31'E).

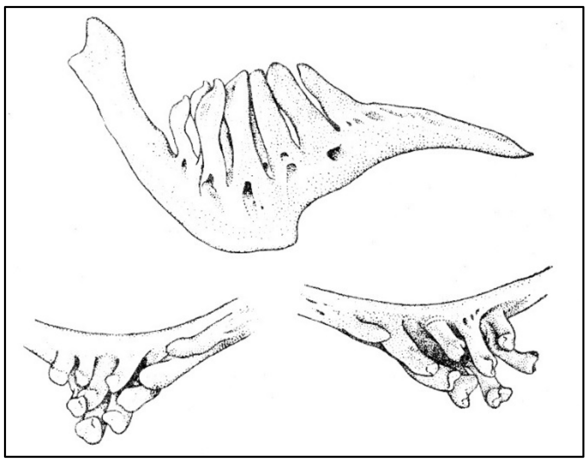
## *Schizothorax zarudnyi*
(Nikol'skii, 1897)



*Schizothorax zarudnyi*
Susan Laurie-Bourque @ Canadian Museum of Nature.



*Schizothorax zarudnyi*, dorsolateral scale,
after Annandale and Hora (1920).



*Schizothorax zarudnyi*, pharyngeal teeth from several
angles, after Annandale and Hora (1920).

*Schizothorax zarudnyi*, CMNFI 1979-0225, Sistan, Hirmand River effluent, 8 May 1977, Brian W. Coad.

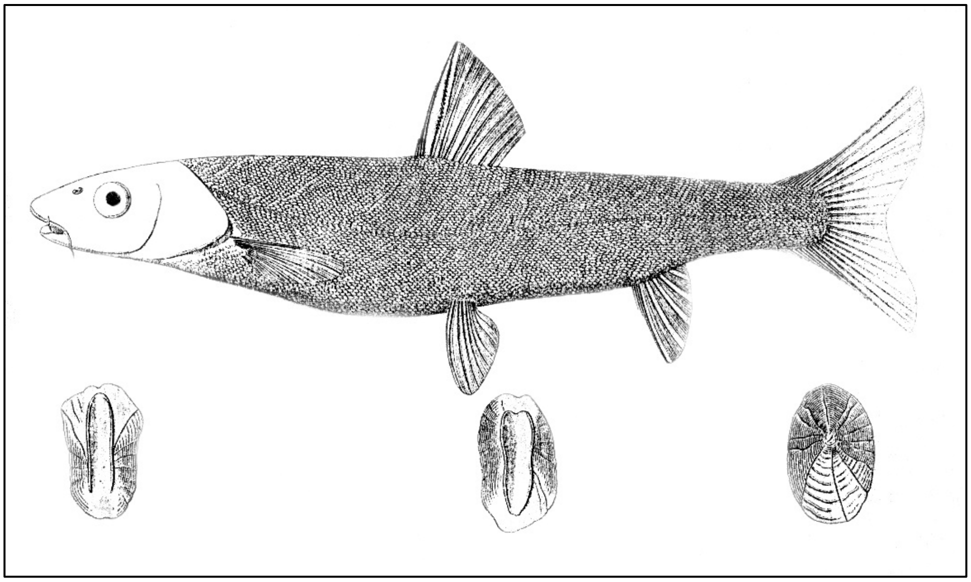
**Common names.** Hamun mahi (= hamun or lake fish), mahi khvaju or khaju (after the historic island in Lake Hamun), sefidak (= white fish), or vatani (A. A. Pasand, pers. comm., 5 November 2000; meaning national or homey, Y. Keivany, pers. comm., 25 September 2018), shir mahi (= milk fish), anjak or anjaq (Fowler and Steinitz (1956) reported three kinds of fish being caught by fishermen in Sistan named anjaq (hence *Oreinus anjac*, see below), mawda (unknown, probably *S. intermedius*) and mahrmahé (= mar mahi, snake fish, probably a nemacheilid)).

[White marinka, in Russian; Sistan marinka].

**Systematics.** The holotype of *Aspiostoma zarudnyi* is in poor condition with the tail detached and the body impaled on a wooden spike when examined by me. Nikol'skii (1897) in his original description stated in Latin "Specimen valde destructum". It is in the Zoological Institute, St. Petersburg (ZISP 11195a) and measures about 26.5 cm standard length. Nikol'skii (1897) and *Catalog of Fishes* (downloaded 31 March 2018) gave the catalogue number as 11115 (*sic*, incorrectly according to Berg (1949)) and the type locality as "Palus Neizar in Seistan. 3.VI.96.". Berg (1949) gave the collection locality as "Neizar near the southern tip of Lake Hamun-i-Farah, western edge of the Helmand delta in northwestern Seistan" based on Zarudnyi (1901).

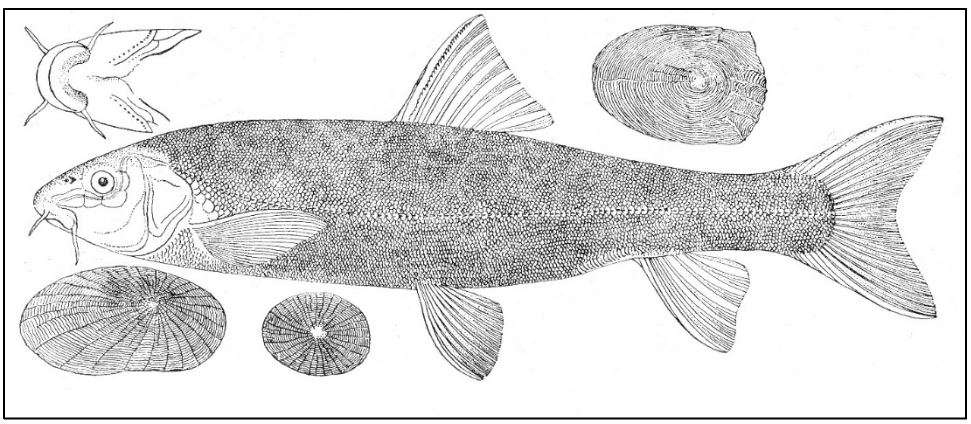
This species was originally described in the genus *Aspiostoma* Nikol'skii, 1897, a synonym of *Schizothorax* Heckel, 1838 (Eschmeyer, 1990). Bianco and Banarescu (1982) placed this species as *Schizopyge zarudny*, the species name being a mis-spelling. *Schizopyge* Heckel, 1847 was regarded by these authors as the correct name for snow trouts without a suctorial disc on the chin (see discussion above under the genus *Schizothorax*).

*Barbus microlepis* Keyserling, 1861 described from "Flüsschen bei Anardareh, zwischen Herat und Lasch" is a synonym and is objectively invalid and pre-occupied by *Barbus microlepis* Bleeker, 1851 from Borneo. Anar Darreh, Afghanistan is at 32°46'N, 61°39'E.



*Barbus microlepis*, after Keyserling (1861).

*Oreinus anjac* Fowler and Steinitz, 1956 from "Zabol, Eastern Iran" is also a synonym as suggested by Saadati (1977) although it may be a hybrid. The holotype of *Oreinus anjac* (ANSP 71949) at 28.1 cm total length is stored in the Academy of Natural Sciences of Philadelphia (Böhlke, 1984).



*Oreinus anjac*, holotype, ANSP 71949,
scales: upper right - large postscapular, lower left - upper lateral predorsal,
middle left - preanal, after Fowler and Steinitz (1956).

Latifi *et al*. (2018) examined Iranian schizothoracines using COI sequences and found this species did not cluster with the other species.

**Key characters.** The only common *Schizothorax* species in Sistan, it is recognised by the large barbels and enlarged scales around the anal fin. This species is closely related to *Schizothorax intermedius* but is distinguished by much smaller paired fins, longer and narrower branchial isthmus, and the scales slightly enlarged at the base of all fins, especially the dorsal and anal (Annandale and Hora, 1920). Also gill rakers are more numerous.

**Morphology.** The body is rounded and relatively elongate, deepest midway between the head and the dorsal fin. The dorsal profile in front of the dorsal fin is convex. The caudal

peduncle is compressed and deep. The snout is rounded and the eye is in the anterior half of the head (postorbital distance is long). The mouth is oblique and usually slightly subterminal but can be terminal or have the lower jaw projecting slightly. Lips are thick. There are two pairs of thin barbels, the anterior ones long to rudimentary in literature sources. The barbels are subequal in length, the anterior ones not reaching the eye and the posterior ones not reaching beyond the eye. The dorsal fin spine is moderate with medium denticles extending almost to the tip. Denticles are proportionately longer and spinier in young. The dorsal fin margin is emarginate and the fin origin is anterior to the pelvic fin level. The depressed dorsal fin does not reach back to the level of the anal fin origin. The caudal fin is deeply forked with rounded tips. The anal fin margin is straight to slightly convex and the fin does not extend back to the caudal fin base. The pelvic fin is rounded and remote from the anus in large fish but extending to it in small fish. The pectoral fin is rounded and does not extend back to the pelvic fin.

Dorsal fin with 3-4 unbranched and 7-8 branched rays, anal fin with 3 unbranched and 5 branched rays, pectoral fin branched rays 16-19, and pelvic fin branched rays 9-10. Lateral line scales 93-115, at least 190 in the scale series immediately above the lateral line. The breast is naked or sparsely scaled. There is a pelvic axillary scale. Large scales are found immediately behind the operculum. The scale sheath around the anal papilla and anal fin extends about one third to half way between the anal fin origin and the pelvic fin base (to the end of the pelvic fin level). Scales are very small, horizontally ovoid and have an almost central focus. Scales are obliquely inserted in the scale pockets on the mid-flank above the lateral line and below the dorsal fin. Scales on the nape are none to minimally imbricate. Radii are found on all fields and are numerous. Gill rakers on the lower arm number 30-41 (Nikol'skii's (1897) count of 25 is incorrect according to Berg (1949); but see below for wider variation of 24-41). Gill rakers are long, reaching the third to the sixth adjacent raker when appressed. The interior margin of each raker is serrated. Pharyngeal teeth are usually 2,3,5-5,3,2, with variants 2,3,5-5,3,3, 2,3,5-5,2,1, 2,3,5-5,3,1, 2,2,5-5,3,2, 2,2,5-4,2,2, 2,3,4-5,3,2, 2,3,4-4,3,2 or 1,2,5-5,3,2, spoon-shaped with a slightly hooked tip. Anterior teeth are more rounded and thicker. The gut is elongate and coiled. Total vertebrae number 47-49. The chromosome number is 2n = 96, NF = 142, comprising nine pairs of metacentric, 14 pairs of sub-metacentric and 25 pairs of acrotelocentric chromosomes, and the fish is a tetraploid (Hosseini and Kalbasi, 2005; Kalbassi *et al*., 2008).

Gharaei (2012) gave morphometric and meristic data. Abtahi *et al*. (2014) described histological aspects of development from day 0 to day 21 after hatching.

Meristic values for Iranian specimens are:- dorsal fin branched rays 7(2) or 8(34), anal fin branched rays 5(35), pectoral fin branched rays 16(1), 17(7), 18(10) or 19(16), pelvic fin branched rays 9(30) or 10(5), lateral line scales 93(1) …., 97(1), 98(2), 99(3), 100(4), 101(5), 102(-), 103(4), 104(-), 105(2), 106(5), 107(2), 108(1), 109(2) …., 113(1) or 114(1), total gill rakers 24(1), 25(1), 26(1), 27(1), 28(1), 29(1), 30(-), 31(5) …., 34(6), 35(2), 36(8), 37(1), 38(2), 39(-), 40(1) or 41(1), pharyngeal teeth 2,3,5-5,3,2(14), 2,3,5-5,3,3 (1), 2,3,5-5,2,1(1), 2,3,5-5,3,1(1), 2,2,5-5,3,2 (1), 2,2,5-4,2,2(1), 2,3,4-5,3,2(2), 2,3,4-4,3,2(1) or 1,2,5-5,3,2(1), and total vertebrae 47(11), 48(11) or 49(4).

**Sexual dimorphism.** Males develop prominent nuptial tubercles on the snout and on the scales. Females have a soft and distended belly during the breeding season (CIRSPE, 2006b).

**Colour.** Overall colour is silvery, the back and head darker with indistinct fine dots. Some fish may be overall white to creamy in appearance with the dorsal and caudal fins darkly

contrasted. The flanks may be spotted with black and some small areas may be more lightly pigmented and appear as indistinct spots or blotches. There are melanophores on the fin rays and membranes. Adult males may have reddish fins and dull red specks on the dorsal surface. Young are silverier than adults. Generally, there is no distinctive pattern on the body and fins. The peritoneum is brown to black.

Colour also varies with the environment. In muddy water, the back and fins are pale olive-green, the flanks tinged with green or pale yellow and the belly pure white while in the yellow water of the reed beds the back and flanks are much darker, almost black, and even the belly is darkish.

**Size.** Reaches 62.1 cm total length and over 2.2 kg. Ahmadi and Wossughi (1988) gave average weights of 300 to 2,000 g in commercial catches while fish more than 12.0 kg have been reported (*Iranian Fisheries Research Organization Newsletter*, 30-31:5, 2002).

**Distribution.** This species is restricted to the Sistan basin of Iran and Afghanistan including from the former in the Hirmand, Kharaji and Sistan rivers, Chahnimeh Reservoirs near Zahak, the Zahak Dam, and the Puzak and Saberi hamuns (Nikol'skii, 1897; Bianco and Banarescu, 1982; J. Holčík, *in litt*., 1996; Elahi Moghaddam *et al*., 2014; Mirzaei *et al*., 2014; Latifi *et al*., 2018). Ghanbari and Jami (2011) and Gharaei (2012) reported it to be present only in the Chahnimeh Reservoirs as the hamun dried out; presumably it recolonises the hamuns from rivers and reservoirs in wetter seasons.

**Zoogeography.** See under the genus description.

**Habitat.** This species is found in rivers, streams, ditches, lakes, dams, pools, ponds and marshes. It is recorded from the open lake, in reed beds and in pools and jubes (= irrigation channels) in Sistan (Annandale, 1921; collection data below). It is the only species in Sistan common in the open lake in winter. Young probably make their way upstream in the flood season as only adults are found in the lake in winter. The species is extremely abundant in pools left in stream beds when the floods recede. Spawning may occur in rivers as fry have not been found in the lakes (*Iranian Fisheries Research Organization Newsletter*, 30-31:5, 2002). Zabihi (2006) characterised it as a potamodromous species and noted that in March and April, if there is no flow in the rivers and thus no migration from the lake is possible, female gonads are reabsorbed. Ghanbari and Jami (2011a) noted that mature fish migrated during April-May from rivers and lakes to cold and well-oxygenated streams for spawning, and migrated back leaving the young behind. Collection data included a temperature range of 24-31ºC (8-9 May 1977), pH 6.2-6.5, conductivity 0.52-1.0 mS, river width 2-10 m, still to medium current, depth 20-100 cm, cloudy or muddy water, a mud bottom, emergent vegetation, and a grassy shore.

**Age and growth.** Sexual maturity may only be attained after 4 years. Zabihi (2006) examined 697 specimens with a length and weight range of 24.5-62.1 cm and 137-2,204 g. Half the male fishes were mature at 29-31 cm and for females at 38-40 cm. Males matured a month earlier than females (Ghanbari and Jami, 2011**.** Zare *et al*. (2011) gave a length-weight *b* value of 3.146 for 36 fish, 14.7-32.0 cm in length, from the Chahnimeh Reservoirs. Gharaei (2012**)** gave length-weight relationships of $y = 0.0118x^{3.2177}$ for 25 females, 20.5-32.0 cm total length, and $y = 0.0035x^{3.3349}$ for 64 males, 14.7-26.7 cm total length, indicating positive allometric growth. Conversely, Rahdari and Gharaei (2012) found *b* values of 2.7869 for females and 2.5137 for males from the Chahnimeh Reservoirs, both negatively allometric. Arshadi and Mirdarharijani (2018) examined 41 fish from the Chahnimeh Reservoirs and found the average weight was 121.7 g, the average length was 22.35 cm, the male:female sex ratio was 1:1.16, and the *b* value was 3.177 showing isometric growth.

**Food.** The diet comprised almost exclusively small fishes in some reports but Gharaei (2012) found a relative gut length of 1.71 for fish 14.7-32.0 cm total length indicating an herbivorous diet. Diet could change with age and habitat restrictions. Arshadi and Mirdarharijani (2018) for their 41 fish from the Chahnimeh Reservoirs found this fish was omnivorous based on a relative gut length of 1.73 (gut to body length), the average feeding intensity was 180.64% with maximum and minimum in May and February at 480.54% and 43.02% respectively. Ghanbari *et al*. (2017) investigated the biodiversity profile of the gut bacterial community by applying 16S rRNA gene 454-pyrosequencing. The lumen and mucosal layer hosted diverse different microbial communities with 10 phyla found, with more diversity in the mucosa, and both having high physiological relevance and playing key roles in gut function.

**Reproduction.** Eggs in fish caught in spring by me were developing but very small. Specimens with mature, yellow eggs have been caught in December. However, this species was mature in Esfand (20 February-20 March), incubation was 6-7 days at 16.20-17.75ºC, maximum egg diameter was 3.8 mm when washed, and the yolk sac was absorbed at 6-7 days (M. Abedi, Islamic Azad University of Savad Kooh, abstract). Zabihy *et al*. (2004) and Zabihi (2006) found maximum oocyte size in March and April at 14-18ºC when the gonadosomatic index was highest at 7.9-9.6. The mean absolute and relative fecundities for fish 460-1,380 g were 26,256 and 34,418 eggs respectively. The species was a total spawner showing a synchronous ovary. Eggs were adhesive to prevent them being washed away by strong currents (CIRSPE, 2006b). Arshadi and Mirdarharijani (2018) for their 41 fish from the Chahnimeh Reservoirs found a condition factor of 1.01% with a maximum in March at 1.3% and a minimum in May at 0.76%. The gonadosomatic index was 1.08% with a maximum in March at 1.75% and a minimum in May at 0.84% indicating breeding in March. The average relative and absolute fecundities were 33,140 eggs/kg and 29,964 eggs respectively.

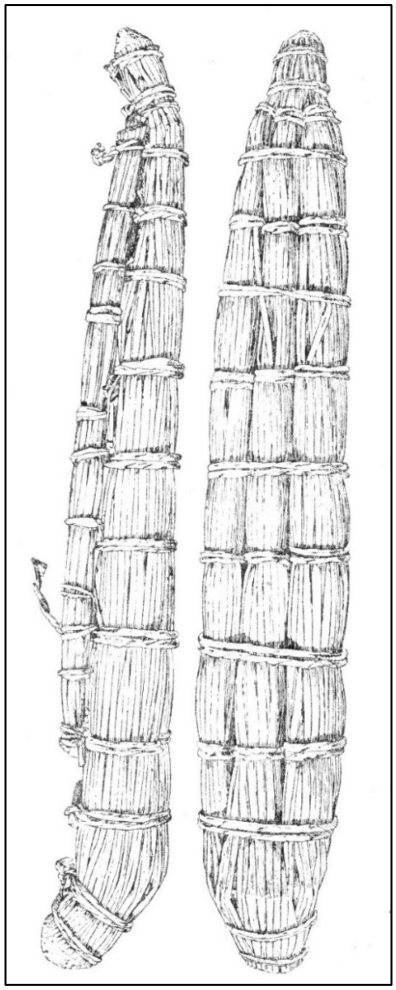
**Parasites and predators.** Datta (1937) described the male of the acanthocephalan *Eosentis rigidus* from the intestine of this species. Barzegar *et al*. (2008) recorded the digenean eye parasite *Diplostomum spathaceum* from this fish. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Lernaea* sp. on this species. Elahi Moghaddam *et al*. (2014) examined fish from the Chahnimeh Reservoirs, Zahak Dam, Puzak Hamun and Saberi Hamun and found the crustaceans *Argulus* sp. and *Lernaea* sp. and the protozoans *Ichthyophthirius multifilis*, *Trichodina* sp. and *Chilodonella* sp. Mirzaei *et al*. (2016) found *Lernaea cyprinacea* and *L. polymorpha* on fish from the Chahnimeh Reservoirs, with a mean intensity of infestation at 7.68.

Mirdar Harijani *et al*. (2013) found that white spot disease (*Ichthyophthirius multifilis*) could be combated most effectively with a combination of malachite green and formalin. Ahani and Alipour Eskandani (2014a) found 37.2% of fish were contaminated by *Staphylococcus aureus* and the polymerase chain reaction test could be used to detect the food poisoning enterotoxins from this bacterium. Ahani and Alipour Eskandari (2014b) found that the gene specific polymerase chain reaction could be used to differentiate between food poisoning or enterotoxigenic *Bacillus cereus* and the non-enterotoxigenic strain, thus ensuring food safety.

**Economic importance.** Annandale in Annandale and Hora (1920) described the fishery for this species in the early years of the 20th century. Annandale commented that the flesh tasted like trout but was bony. The bones could be softened by cooking in vinegar. This fish is still caught and eaten and appears in local markets. Ahmadi and Wossughi (1988) cited an

annual catch of 300-500 t while *Iran Daily* (24 August 2006) gave 700-1,000 t before a drought.

Annandale and his assistants became sick from eating the eggs of this species but he maintained that the local fishermen ate it without any deleterious effects. Fish were caught in a net about 4 feet (1.22 m) deep and 100 feet (30.5 m) or longer anchored at each end by a tamarisk stick stuck into the lake bottom and with the bottom of the net on the lake bed and the top of the net slightly above the surface. The net was positioned in relation to the wind, and therefore the prevailing currents, so it formed a semi-circle. The net was arranged in a gap in the reed beds or just outside the reeds in the open lake if the weather was exceptionally calm. Pools in the reeds were kept open to facilitate the fishing. The fishermen riding their *tutins* (reed boats) would drive the fish into the net by beating the water with poles and ululating.



Two views of a tutin or reed boat,
after Annandale and Hora (1921).


Sistan, reed boat or tutin, 9 May 1977, Brian W. Coad.

The two ends of the net were then lifted out of the water by the men in the two end boats such that the net formed a bag. The net was drawn into the two boats as rapidly as possible. A similar but shorter net was used to drag small channels while the men using it waded. A small-meshed bag net, attached to one horizontal and two upright poles, was also used in pools of dry stream-beds. The net was dragged by ropes, the men wading through the water. Some large fish were killed in the flooded swamps by striking at them with swords. Another net consisted of a bag about 7 feet (2.14 m) long and 6 feet (1.83 m) by 2 feet (0.61 m) at the mouth. The mouth was held open by poles tied together at one end to make a fork. The fork pivoted on a post on the bank. The mouth of the net had fine lines across it, the lead string of which was held by the fishermen to warn him that a fish had entered the net so he could pull the net out of the water to retrieve the fish. The net was placed along a bank where the current swirled forming a backwater, at the mouth of a small canal, or as the focus of a line of stakes blocking a channel. The season for this type of net began as early as August or not until October. It lasted several weeks. March and April could also be a favourable time if the river was not very full but the fish did not move as actively. The large fish caught were attracted to feed on the numerous small fish which migrated up river along the shore and were checked where backwaters met the main flow.

A more recent description of fishing in Sistan is found in Fowler and Steinitz (1956). Fishing took place in fall on rivers and in the lake, preferably the early evening or morning when it was cool. River fishing was preferred to lake fishing and some fishermen never went out onto the lake. Lake fishing using boats lasted up to 3-5 days at a time. River fishing was carried out with a cotton-thread seine weighted by stones at the bottom and with gourds as floats. The seine was tied to sticks at each end and the sticks to ropes leading to shore. Four to ten men could own a seine and the catch was divided among those fishing that day. Fishing was done in teams of 4-7 men or often in two teams with two nets. Half the men were on one side of the river and half on the other, pulling each other's nets in and out of the water. Only large, fat fish were kept, the others being thrown back. One net caught 30-40 fish in a day

which were then sold in Zabol. Women never fished nor were present during fishing as they supposedly brought bad luck. Fish were always cooked before eating as eating raw fish was reputedly fatal.

**Experimental studies.** Rigi and Pakzad (2015) found that accumulation of copper, lead, nickel and zinc in muscle tissue was higher than acceptable limits, threatening both fish and human health. Khandan Barani *et al*. (2016) found interactions between biological systems and lead exposure, in that acetyl cholinesterase in the brain and gills was significantly inhibited and alanine and aspartate aminotransferase activity increased in the brain and liver. Khandan Barani and Miri (2017) showed that cadmium was more toxic than zinc to this fish and most toxicity was in the liver. Assessing levels of metabolic enzymes in liver tissue and acetylcholinesterase enzyme in brain tissue has potential as suitable indicators of heavy metal pollution in the aquatic ecosystem. Zolfaghari (2018) found lead concentrations in muscle tissue were higher than World Health Organization limits while mercury was lower. A maximum consumption of 0.019 kg/day gave no potential health risk. The maximum allowable fish consumption rate per month was 2.54 meals. Yavari *et al*. (2013) found the $LC_{50}$ 96 h value was 14.7 mg/l for the insecticide diazinon. Toxicity was low but some clinical symptoms were lordosis, neural paralytic syndrome, loss of balance and swimming in half circles, expressive pigmentation dorsally, and blocking of respiration movements. Various histopathological changes were also noted.

This species has been investigated for fish farming and its nutritional composition and value in Sistan. Aghili (2014a) found that Chinese carps had better survival and yields than snow trout in Sistan. Dehmarde *et al*. (2013) found that the best diet carbohydrate levels in juveniles were 32.9-36.77%. Jahangoo *et al*. (2013, 2014) showed that the addition of 3.0 g/kg of the prebiotic mannan oligosaccharide in the diet improved growth performance, final production, nutrient composition, and carcass fish protein. Rahdari *et al*. (2013) found that diets with 5-8% lipid were the most suitable levels for fingerlings. Shariari Moghaddam *et al*. (2014) gave details on the early ontogenetic development of the digestive tract from hatching to 21 days, critical data for optimal rearing and artificial diet design in aquaculture. Khammar *et al*. (2015) showed that a dietary protein level of 25% was optimal for proper growth and feed conversion in aquacultured fingerlings. Sheibak *et al*. (2015, 2016) investigated the activity of the enzymes α-amylase, lipase and trypsin in the intestine, finding the former was the most active and variation in activity of all in differing parts of the intestine. A food ration based on carbohydrates could be used for this species of fish. Khandan Barani et al. (2016) found no significant effect of dietary nucleotides on fingerling growth but could improve response to acute stress. Sanchooli *et al*. (2017) found lysine, an amino acid, fed at 17 g/kg diet was optimal for growth, feed efficiency and body composition of juveniles. Khandan Barani *et al*. (2019) concluded that a 4.9-5.2% body weight per day ration was optimal for growth, conversion efficiency and body composition of juveniles and was favorable economically. Afshari *et al*. (2021) showed growth performance and haemato-immunological responses were affected by the chemical forms of copper and iron but the nanoparticulate forms were more effective in this aquaculture candidate.

Rahimabadi *et al*. (2009) assessed the lipid quality of this species and found it to have a higher nutritional value than *Schizocypris altidorsalis*. Zakipour Rahimabadi *et al*. (2009) gave chemical composition of muscles, noting variation by season and sex. Zakipour Rahimabadi (2015) gave details of the fatty acid profile in muscle and liver tissue of both sexes. Khajavi *et al*. (2016) determined the optimum conditions for protein hydrolysis of waste (skin, head,

viscera, liver, etc.) to be used as animal feed, fish feed and fertiliser. The pepsin enzyme concentration was optimum at 5%, substrate amount at 5 g, temperature at 37°C and hydrolysis time at 72 hours. Antioxidant activity of the hydrolysates had a radical scavenging activity of 50.06% using the chemical compound DPPH as assay.

Keykha *et al*. (2015) determined that metalonic sumac (*Rhus coriaria*) extract was an effective and environmentally friendly antifungal agent at 500 mg/l for incubating fish eggs.

Abedi (2003) found highest gonadosomatic indices and stage 4 of sexual maturity in March and so hormone treatments were carried out in this month. Temperature was an important factor in success (14-17ºC) as was flowing water, egg diameters were 1.9-2.3 mm and 3.8 mm when fertilised, eggs hatched after 6-7 days at mean water temperature of 17.08ºC, and after a month newly-hatched larvae were 29.41 mm long. CIRSPE (2006b) and *Iran Daily* (24 August 2006) also gave details on artificial reproduction of this species. Males over 600 g and females over 900 g were found to be suitable for breeding, ideal water temperature range was 18-22ºC, fecundity range was 24,300-37,640 eggs for fish 0.8-1.1 kg, egg size was 1.54 mm (presumably not water hardened; see above), and survival from egg to 11 mm fingerling was about 10%. Gharaei *et al*. (2010, 2011a, 2011b) investigated induced spawning of this species using synthetic hormones in order to breed the fish for aquaculture (ovaprim, a commercial spawning inducing agent, was effective) and noted also the deleterious effects of the long-term drought of 1997-2010 and the introduction of Chinese carps to Sistan. Rezvani Gilkolaei *et al*. (2012) caught 331 spawners weighing 800-2,450 g from the Chahnimeh reservoirs in early autumn. Ovulation was stimulated with three stimulators: pituitary extract (3-6 mg/kg body weight), GnRHa (20-30 mg/kg body weight) and anti-dopamine (10-15 mg/kg body weight) given in 2-3 doses to the breeders. In mid-March of 2007 (12-13ºC water temperature) response to the injection was 25%, In April of 2008 (14-16ºC water temperature) response to the injection was 65%. Twenty female breeders released their eggs completely, three breeders released half of their eggs and seven released one-third of their eggs. Larvae were fed with a mixture of powdered milk and egg yolk followed by decapsulated *Artemia* cysts and nauplii of *Artemia*, and then on formulated starter diets used for carps. Larvae were transferred to two 1,200 sq m earthen ponds where they reached a body weight of about 1 g. Larvae were fed with a starter feed. About 350 thousand larvae were stocked in two earthen ponds. Artificial breeding in *Schizothorax* was successfully achieved at 14-16ºC in a flow through system using hormone therapy (combination of GnRha and anti-dopamine) and larvae could be easily cultured in earthen ponds. However, this species exhibited lower growth rates as compared to carps and its high expense could be important in economical feasibility. Rahdari *et al*. (2013, 2014) examined the use of the synthetic hormones ovaprim and human chorionic gonadotropin (hCG) in artificial propagation. Spawning rate and mean working fecundity were 83.3% and 39,531 eggs respectively and relative fecundity was 28,410 eggs/g (*sic*), and other parameters were detailed. The highest hormonal stimulation effectiveness was seen when only ovaprim was used although a shorter latency time (time from first injection to ovulation, 40 hours and 40 minutes here) was seen when high doses of ovaprim and hCG were used.

Arabnejad *et al*. (2014) found that ovaprim and common carp pituitary gland hormonal injections had more beneficial effects than hCG on spermatological parameters. Arabnejad *et al*. (2015) found that the three hormones had different effects on biochemical parameters of seminal plasma, with ovaprim having more effects. Arabnejad *et al*. (2016) investigated spermatological and biochemical parameters finding a significant relationship between sperm

motility and seminal plasma components, especially sodium and potassium ions, useful for preparing the appropriate preserving and diluent solutions in artificial breeding. Arabnejad *et al*. (2016) injected ovaprim hormone into mature males three times over seven days, followed by stripping of sperm. No sperm was obtained after the third injection, indicating appropriate intervals were needed. Gharaei (2016) studied the effects of semen diluent solutions on improvement of reproduction performance, and found that 7.305 g NaCl, 0.735 g $CaCl_2.2H_2O$, regulated in pH 8.4 and solution in 1.0 l of distilled water was the most effective.

Khandan Barani *et al*. (2019) used blood biochemical parameters for their diagnostic potential in assessing nutritional status for healthy juveniles, and found glucose, aspartame aminotransferase and thyroxin levels were responsive to starvation. Dahmardeh *et al*. (2021) investigated changes in pancreatic digestive enzymes from the egg to the larval phase. The activity of the trypsin and lipase enzymes increased from the egg to the four days larval stage, and their highest activities were observed at the end of the yolk sac absorption stage. There were no significant differences in trypsin and lipase enzyme activity between the 3 and 1 and 4-days-old larvae, while significant differences were observed between 4-days-old larvae, fertilised eggs and newly hatched larvae. Rahdari *et al*. (2021) provided baseline data on ionic (calcium, phosphorus, magnesium, sodium and potassium) and organic (glucose, cholesterol, total protein and albumin) composition of blood serum and semen composition in male broods.

Afshari *et al*. (2016) studied salinity stress, noting continuous droughts and decline of well-water quality resulting in salinity increases. They found a decrease in growth rate with salinity increase and biochemical and blood parameters also reflected salinity stress. Shahriari Moghadam *et al*. (2018) found that juveniles could be cultivated in saline water (10 g/l) but growth was low. A gradual transfer to more saline water resulted in increased tolerance (13 g/l). The $LC_{50}$ 96 h was 10.52 g/l. Gill tissue damage was observed, epithelial lifting and necrosis, for example.

Mirdar Harijani and Tofighi Moghadam (2017) found that lavender (*Lavandula officinalis* (= *L. angustifolia*) essential oil could be used at 200 p.p.m. as a sedative and at 300 p.p.m. as an anaesthetic without side effects in aquaculture activities.

**Conservation.** Ahmadi and Wossughi (1988) stated that introductions of various fishes such as *Cyprinus carpio*, *Carassius auratus*, *Ctenopharyngodon idella* and *Hypophthalmichthys molitrix* were possible sources of competition for native species such as this schizothoracine since they are voracious, take spawning sites and carry diseases and parasites. Native catches have decreased in favour of introduced species.

Ghanbari and Jami (2011) classed this species as endangered and Jouladeh-Roudbar *et al*. (2020) as Data Deficient.

**Sources.** Type material:- *Aspiostoma zarudnyi* (ZISP 11195a) and *Oreinus anjac* (ANSP 71949).

Iranian material:- CMNFI 1979-0072, 1, 199.1 mm standard length, Sistan, river near Zabol (30º58'N, 61º28'E); CMNFI 1979-0223, 1, 34.4 mm standard length, Sistan, irrigation ditch 1 km south of Lutak (30º45'N, 61º24'E); CMNFI 1979-0225, 11, 182.2-225.3 mm standard length, Sistan, Hirmand River effluent (30º58'N, 61º28'E); CMNFI 1979-0226, 2, 146.8-167.2 mm standard length, Sistan, pool near Kuh-e Khajeh (30º57'N, 61º17'E); CMNFI 1979-0231, 2, 23.1-25.8 mm standard length, Sistan, jube 3 km from Zabol (31º01'N, 61º32'E); CMNFI 1979-0232, 2, 26.3-26.5 mm standard length, Sistan, ditch 11 km from Zabol (ca. 30º58'30"N, ca. 61º36'E); CMNFI 1979-0235, 13, 148.4-193.7 mm standard length, Sistan, effluent of Hirmand River (30º54'30"N, 61º41'E); CMNFI 1979-0237, 8, 24.4-45.3 mm

standard length, Sistan, ditch 18 km south of Zabol (30º53'N, 61º27'30"E); BM(NH) 1920.1.20:35, 1, 232.5 mm standard length, Sistan, near Lab-e Baring (ca. 31º07'N, ca. 61º12'E); ZMH 5902, 2, 372.3-369.7 mm standard length, Sistan, Hamun See (no other locality data); ZMH 5903, 3, 274.2-298.7 mm standard length, Sistan, Hamun See (no other locality data); ZMH 6088, 2, 48.3-136.1 mm standard length, Sistan, Rud Sistan (no other locality data).

## Genus *Tariqilabeo*

Mirza and Saboohi, 1990

This genus contains about seven species found from Iran to India with two species in Iran. Species were previously placed in the genus *Crossocheilus* Kuhl and van Hasselt in van Hasselt, 1823, a genus now restricted to Southeast Asia (Yang *et al*., 2010, 2012), and in *Gonorhynchus* McClelland, 1839 (see Kottelat (2016) for discussion and variant name spellings). Mention of the genus in the text below from literature is abbreviated to *T*. for *Tariqilabeo* for simplicity, although the original work may use either of the two above genera, or even *Discognathus* Heckel, 1843 as applied to these fishes.

Kottelat (1987) retained the spelling *Crossocheilus* as first reviser. The name was spelt *Crostocheilus* early in the text but this has never been used again and *Crossocheilus* appeared with the description. *Crossochilus* Günther, 1868 is an incorrect emendation (Eschmeyer, 1990). Much earlier literature on the Iranian species appears under these names and, more recently, under *Gonorhynchus*.

The genus is characterised by an elongate body with a rounded belly, a small head, the mouth is inferior and transverse, the crenulated or fringed upper lip being continuous with the snout (not separated by a groove), i.e., a rostral cap covers the upper lip, upper lip very thin or absent, widening obviously at the mouth corner connecting the upper jaw to the lower lip, lower lip free only on anterior and lateral edges, posterior edge connected to underside of the head (no mental disc), the lower jaw has a horny covering and behind this are several rows of lobate papillae (a diagnostic character after Mirza and Saboohi (1990)), a sublachrymal groove uniformly narrow from mouth corner to rostral barbel, rostral lobe absent, 1-2 pairs of barbels, gill membranes attached to isthmus, dorsal and anal fins short and spineless with 8 branched dorsal rays, dorsal fin origin midway between snout and caudal fin base and well in advance of pelvic fin origin, the lateral line is complete, scales are large to moderate in size, the intestine is very long, and the peritoneum is black. Ciccotto and Page (2016) gave further details and comparison with the genus *Crossocheilus*.

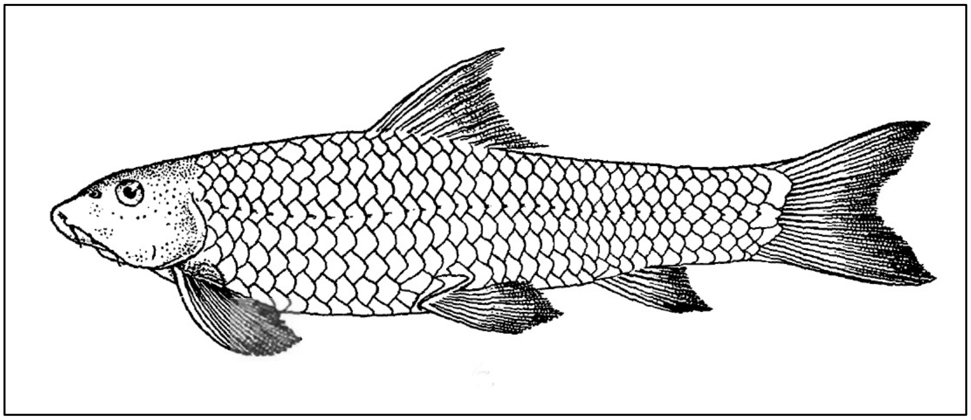
The lower surface of the head bears an “adhesive apparatus”, the mechanism of which has been investigated by Singh (1993) for *T. latius latius*, a taxon not found in Iran. The fringed upper lip acts as a food strainer as well as part of the adhesive apparatus. Both this lip and the area behind the lower lip are heavily tuberculate with glandular openings and irregularly arranged hard ridges. Mucus from the glands in conjunction with the ridges holds the fish to the substrate.

The following table summarises some key distinguishing characters of the Iranian species of *Tariqilabeo*.

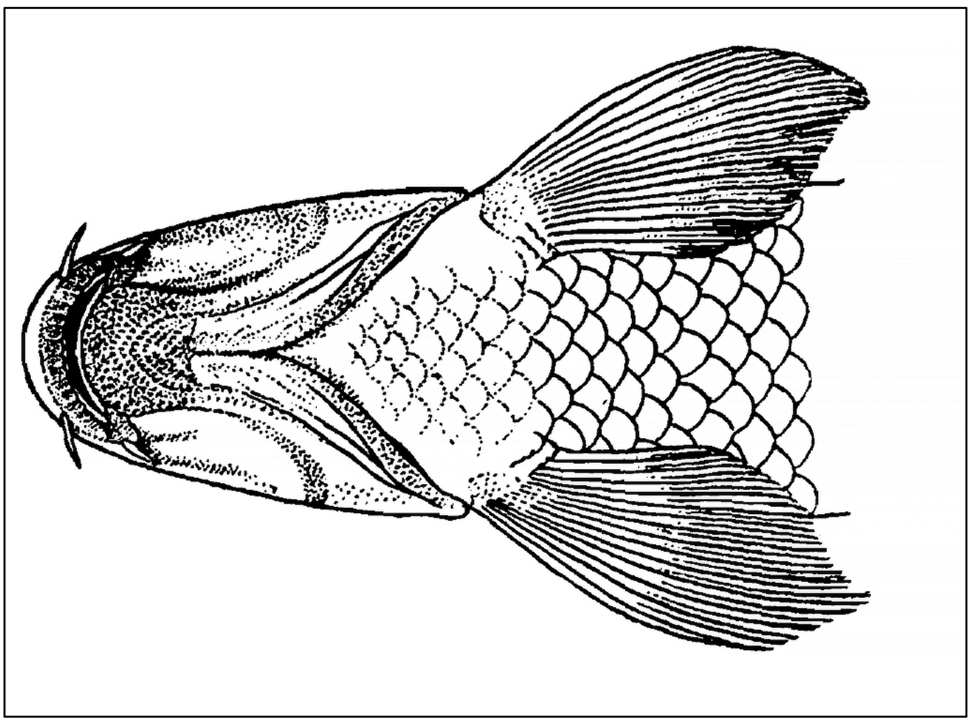
| Species/ Characters | Barbels | Rostral barbel length | Maxillary barbel | Scales between anus and anal fin | Total gill rakers | Distribution |
|---|---|---|---|---|---|---|
| *T. adiscus* | 4, | 12.2-16.8% | 5.6-10.5% | 3-5 | 17-25 | Sistan |

| | | | | | | |
|---|---|---|---|---|---|---|
| | long | head length | head length | (usually 4) | (mostly 19-21) | |
| *T. diplochilus* | 2-4, short | 5.5-11.4% head length | 1.4-4.1% head length | 2-3 | 20-25 (mostly 23-25) | Hamun-e Mashkid, Makran |

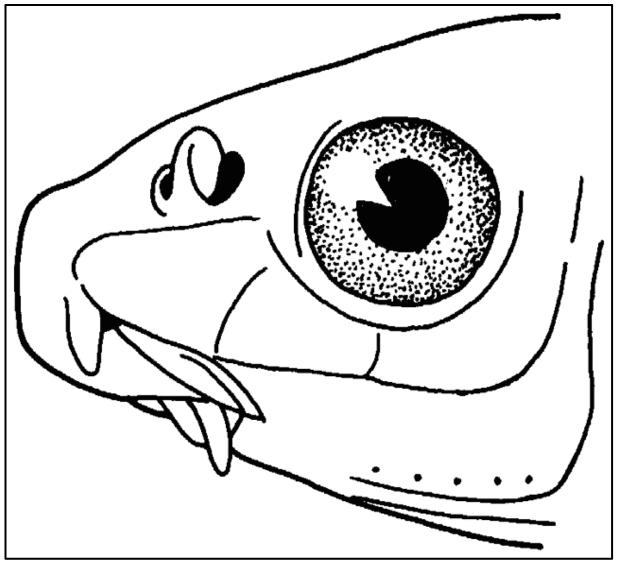
## ***Tariqilabeo adiscus***
(Annandale, 1919)



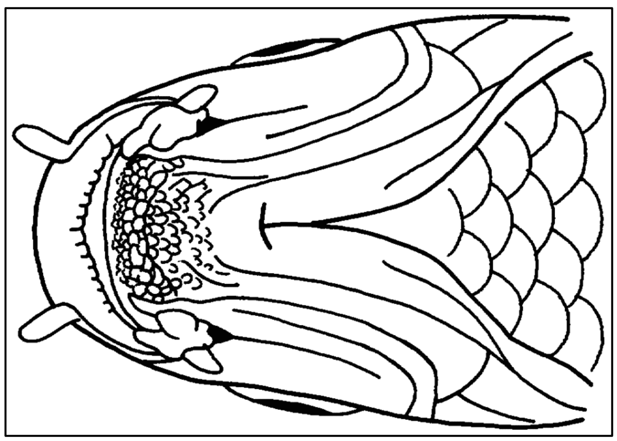
*Tariqilabeo adiscus*, syntype, after Annandale (1919).



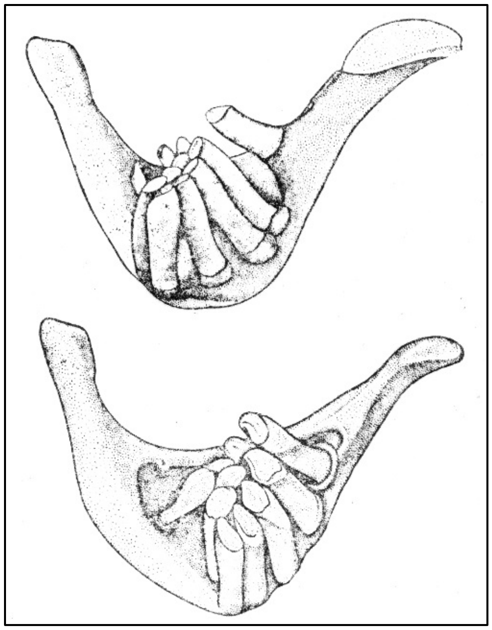
*Tariqilabeo adiscus*, syntype, ventral head, after Annandale (1919).



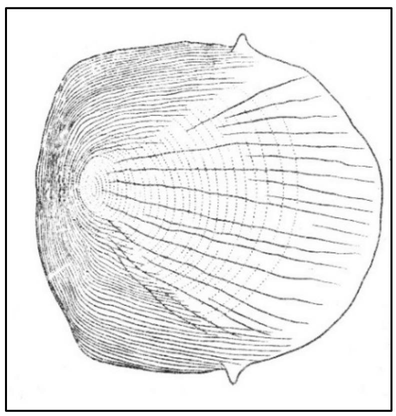
*Tariqilabeo adiscus*, ZISP 25411, lateral head, Sistan, Nasratabad, after Berg (1949).



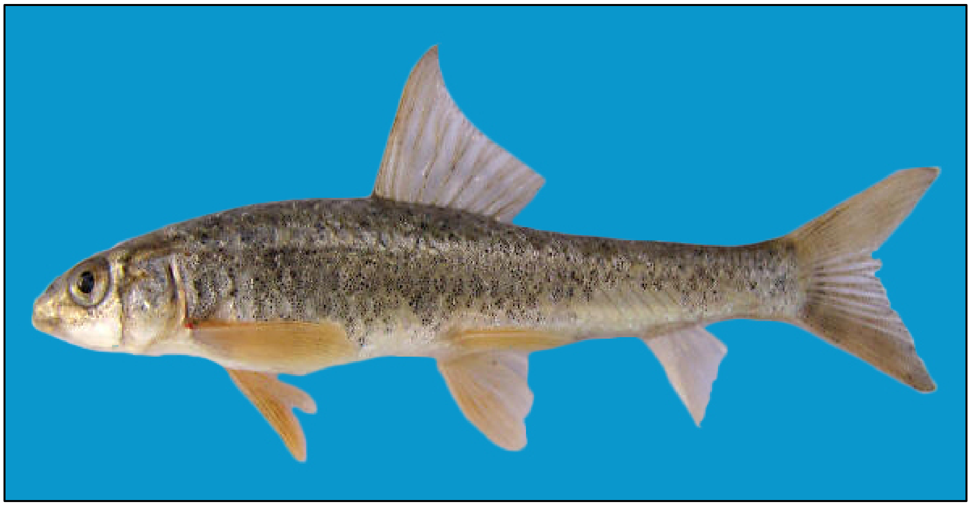
*Tariqilabeo adiscus*, ZISP 25411, ventral head, as above, after Berg (1949).



*Tariqilabeo adiscus* pharyngeal teeth,
after Annandale and Hora (1920).



*Tariqilabeo adiscus* dorsolateral scale,
after Annandale and Hora (1920).



*Tariqilabeo adiscus*, Sistan, Zahak, Sistan River, January 2012, Keyvan Abbasi.

**Common names.** Mahi-ye jolbak-khar-e Sistan (= Sistan algae-eater fish), sanglise Sistani (= Sistan slippery rock fish).

[Sistan algae-eater, Sistan latia].

**Systematics.** Bianco and Banarescu (1982) and Bănărescu (1986) considered *Discognathus adiscus* Annandale, 1919 described from Sistan (type locality discussed below) to be a synonym of *Crossocheilus latius diplochilus* with syntypes of this latter taxon in the Naturhistorisches Museum Wien under NMW 48820 (7 fish). Bănărescu (1986) cited one fish under NMW 48420 as possibly the holotype but this specimen is dated 1839 which is anachronistic. Berg (1949) considered *Discognathus adiscus* to be a distinct species and DNA and morphological evidence confirms this (Sayyadzadeh *et al*., 2015). Ciccotto and Page (2016), however, considered this species as a synonym of *Gonorhynchus* (= *Tariqilabeo*) *diplochilus* when material from the Indus and Helmand rivers are considered. Their material from the Helmand River, which drains to Sistan, was from Kandahar, Afghanistan. Overlap between *T. adiscus* and *T. diplochilus* was found in such characters as barbel lengths, gill raker counts and scales between the anus and anal fin insertion used in part by Sayyadzadeh *et al*. (2015) to distinguish these species. Sayyadzadeh *et al*. (2015) also used molecular evidence to resolve these species as monophyletic clades and Ciccotto and Page (2016) did not incorporate any molecular data. They noted the need for broad sampling of *T. diplochilus* from India to Iran with additional morphological and molecular data to further test these conflicting views.

Characters advanced by Berg (1949) for separating the two species were number of barbels (four in *adiscus*, two in *latius diplochilus* where mouth angle barbels are absent or rudimentary, not the rostral ones as implied by Bianco and Banarescu (1982)), upper lip fringe (barely developed in *adiscus*, distinctly developed in *latius diplochilus*), the posterior gas bladder (conical in *adiscus*, elongate cylinder in *latius diplochilus*), and papillae on the lower lip and chin (rudimental in *adiscus* and *latius diplochilus* but the latter has almost free lateral edges and an attached posterior end - this condition is not specified for *adiscus*).

Four fish from the Hamun-e Mashkid and Makran basins of Iran (*T. diplochilus*) have a fold in the flesh behind the tuberculate area - these latter fish are very small however, 20.8-27.8 mm standard length. My observations of the posterior gas bladder development indicated a great individual variation in form for *T. adiscus*:- the gas bladder may be conical, elongate and tapering, rounded posteriorly, expanded posteriorly, rounded posteriorly after a constriction, or

even a narrow elongate cylinder supposedly characteristic of *T. latius* (and presumably *diplochilus*). Fringe development of the upper lip is also quite variable and seems to be relatively well-developed in larger Sistan fish.

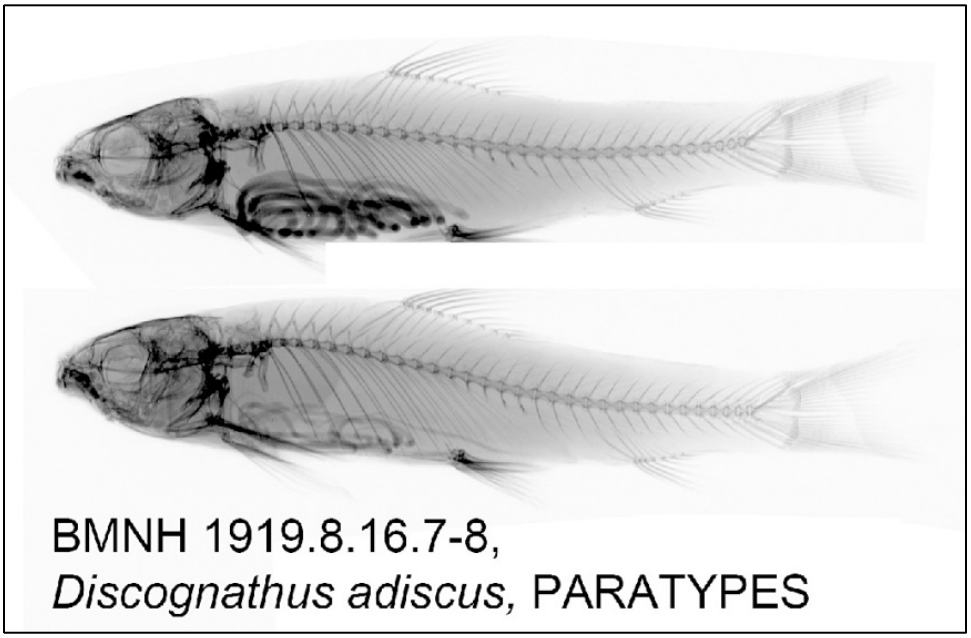
Karaman (1971) described a new genus, *Hemigarra*, for *Tylognathus elegans* Günther, 1868 and *Discognathus adiscus* Annandale, 1919. He placed *Crossocheilus adiscus* as the Sistan subspecies of his *Hemigarra elegans* (= *Garra elegans*) which is found in Mesopotamia (Iraq). Karaman (1971) distinguished the two subspecies by the former having densely arranged papillae on the chin as opposed to sparse papillae. Bianco and Banarescu (1982) and Bănărescu (1986) stated that *C. adiscus* is not related to *Hemigrammocapoeta* (= *Garra*) *elegans* but is a typical *Crossocheilus* species.

The type locality of *Discognathus adiscus* is Sistan by implication, as no locality was given for the holotype in Annandale (1919b). Menon and Yazdani (1968) concurred. Distribution was given as “small watercourses and pools in the plains of Seistan” and “Nasratabad, irrigation channel in Consulate garden; pool in the desert 5 miles (= 8.1 km) south of Nasratabad; pools in stream-bed 12 miles (= 19.3 km) north of Nasratabad; channels in the reed-beds of the Hamun-i-Helmand near Lab-i-Baring, and channel leading out of the Hamun 12 miles (= 19.3 km) east of Lab-i-Baring; small watercourse, Lutak, southern Seistan”, and one of these is presumably the type locality.

Annandale (1919b) cited ZSI 9763/1 as the holotype catalogue number. Twenty syntypes of *Discognathus adiscus* are in the Zoological Survey of India, Calcutta (ZSI F9758/1) (Menon and Yazdani, 1968). Three syntypes are in the Zoological Institute, St. Petersburg (ZISP 25411) from “Nasratabad, Seistan, Indian Museum, Dr. Hora” and measure 38.0-43.4 mm standard length. Two paratypes (listed as cotypes) measuring 44.8-45.5 mm standard length from “Jellalabad” with the annotation “Ind. Mus. Ex. F 9762/1” are in the Natural History Museum, London (BM(NH) 1919.8.16:7-8; the outside had 1919.3.16:7-8, incorrectly).


*Discognathus adiscus*, paratypes, BM(NH) 1919.8.16:7-8,

http://data.nhm.ac.uk/object/c34f80d8-af08-408d-9600-a6002ba48c36,
retrieved: 02 Feb 2019.




*Discognathus adiscus*, paratypes,
http://data.nhm.ac.uk/, retrieved: 02 Feb 2019.

**Key characters.** This species is distinguished from its relative in Iran by having two pairs of long barbels (rostral barbel 3-4% standard length, 12.2-16.8% head length, maxillary barbel 1.4-2.7% standard length, 5.6-10.5% head length), total gill rakers usually 19-21 and scales between anus and anal fin 3-5, usually 4 (Sayyadzadeh *et al*., 2015).

**Morphology.** The body is fairly elongate with a rounded abdomen. The head is rather small, flat and compressed and the snout is prominent and rounded. The eye is situated in the anterior half of the head. The mouth is inferior and the gape is straight. The upper lip is well-developed and continued as a fold at the mouth corners. The upper lip covers the upper jaw, is granular or tuberculate and has a marginal fringe, variably developed and most apparent in larger fish. The lower lip is only apparent at the sides and the exposed lower jaw has a granular or tuberculate pad without a free posterior margin but with almost completely free edges. Horny jaw sheaths are present but are not very thickened. Four relatively long barbels are present, the rostral ones longer than those at the mouth corner. The pelvic fin origin is opposite the fourth branched dorsal fin ray and the pelvic fin reaches or falls short of the anus. The swim bladder has two chambers, the anterior one elliptical and the posterior one greatly variable. The swim bladder may be conical, elongate and tapering, rounded posteriorly, expanded posteriorly, rounded posteriorly after a constriction, or even a narrow elongate cylinder supposedly characteristic of *T. latius*. Illustrations of the swim bladder are given in Sayyadzadeh *et al*. (2015).

Dorsal fin with unbranched rays 2-3 and branched rays 8-9, modally 8, anal fin unbranched rays 2-3 and branched rays 4-5, modally 5, pectoral fin branched rays 14-17, and pelvic fin branched rays 7-10, modally 8. Lateral line scales 34-38. Scales may have short dorsal and ventral projections from the margin at about one-third of the scale length from the posterior edge. There is a pelvic axillary scale. Scales have 9-11 primary radii on the posterior

field and are elongate with a notably anterior focus. Radii in large fish are parallel rather than divergent. Total gill rakers number 17-25, and are small reaching the adjacent or second raker when appressed. Pharyngeal teeth are usually 3,3,5-5,3,3 or 2,4,5-5,4,2, depending on how the crowded teeth are counted; major row teeth are usually 5 but may be 4 or 6, middle row teeth are 3 or 4, and minor row teeth 2 or 3, more rarely 1 (this difficulty in assigning teeth to rows is the reason for omitting frequency distributions below). Supernumerary teeth may be present to further confuse counts. The crown of major row teeth is flattened, the anterior tooth may be rounded and some teeth may have a small hooked tip. The gut is very long and complexly coiled. Total vertebrae number 34-37. The chromosome number is probably 2n = 48 (Klinkhardt *et al*., 1995).

Iranian fish from Sistan, including the syntypes, have the following meristic characters:- dorsal fin branched rays 8(78) or 9(1), anal fin branched rays 5(77), pectoral fin branched rays 14(28), 15(37), 16(12) or 17(1), and pelvic fin branched rays 7(2), 8(72) or 9(4). Lateral line scales 34(12), 35(11), 36(30), 37(32) or 38(4). Total gill rakers 17-25, but not countable with great accuracy since the smallest rakers are difficult to detect at the ends of the arch. Total vertebrae 34(6), 35(23), 36(9) or 37(1). The two paratypes of *D. adiscus*, BM(NH) 1919.8.16:7-8, have 34 and 35 vertebrae.

**Sexual dimorphism.** Unknown.

**Colour.** The back is bluish-grey or brownish to greenish with irregular spots in some populations and the belly light pink to yellowish-white or silvery-white. Fins are pink and the dorsal and caudal fins have a grey tinge. The flank has a bluish, mid-lateral stripe and in preserved fish scattered melanophores, or small blotches of less than scale size, or clumps of melanophores centred on upper flank scales and more dispersed on the lower flank. There is a broad stripe along the back mid-line. Fins in preserved fish are mostly immaculate except in the larger fish with some melanophores lining rays basally. The caudal fin is distinctive in larger fish in having the rays of the lower half of the fin heavily pigmented while the upper half rays are only lightly pigmented. The peritoneum is dark brown to black.

**Size.** Attains 93.2 mm standard length.

**Distribution.** This species is found in the Sistan basin of Iran and Afghanistan. In Iran in the Hirmand and Sistan rivers, the Helmand and Puzak hamuns and the Chahnimeh Reservoirs (Nikol'skii, 1899; Annandale, 1919b; Berg, 1949; Bianco and Banarescu, 1982; J. Holčík, *in litt*., 1996; Abdoli, 2000; Latifi *et al*., 2018; K. Abbasi, see photograph above).

**Zoogeography.** This distribution in Iran marks part of the western limit for the genus and the relationships of the species lie to the east.

**Habitat.** Very abundant in small streams, including those with rocky or muddy beds, jubes (= irrigation ditches), channels in reed beds, marshes, pools, rivers, and the hamuns. This species is found in large schools in Sistan in still or slow-flowing water, on the bottom during the day but it may swim at the surface in the evenings. It is common in the smallest permanent water channels but Annandale and Hora (1920) reported it to be in small numbers in the reed beds in winter and these were dead or dying, perhaps because of low oxygen conditions associated with vegetation decay. Large numbers die each year in drying stream beds as salt content increases and the water is fouled by sheep and goats. Collection data included a temperature range of 22-31ºC, pH 6.2-8.1, conductivity 0.53-4.9 mS, river and pool widths 6-120 m, slow to fast current, water depth 20-150 cm, clear or muddy water, mud or concrete bottoms, encrusting algae, submergent and emergent vegetation, and a grassy shore.

**Age and growth.** Zare *et al*. (2011) gave a low length-weight *b* value of 2.455 for 88

fish identified as *C. latius*, 6.5-13.6 cm in length, from the Chahnimeh Reservoirs, Sistan.

**Food.** Presumably similar to its relative.

**Reproduction.** Iranian adult specimens were caught in May in Sistan and showed signs of developing reproductive organs suggestive of summer spawning.

**Parasites and predators.** None reported from Iran.

**Economic importance.** None.

**Experimental studies.** None.

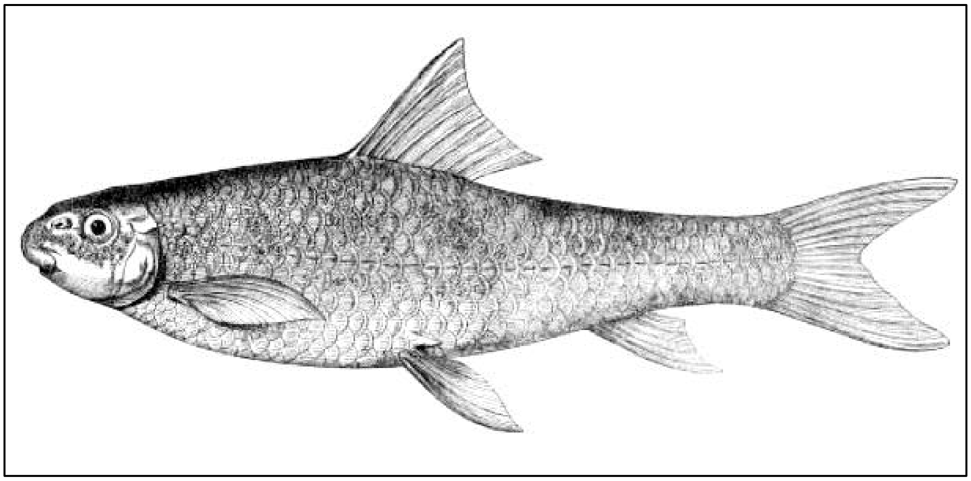
**Conservation.** Population levels vary but no assessment of threats has been undertaken. Jouladeh-Roudbar *et al*. (2020) listed it as of Least Concern as it is widespread and has no major threats.

**Sources:** Type material:- *Discognathus adiscus* (BM(NH) 1919.8.16:7-8 and ZISP 25411).

Iranian material:- CMNFI 1979-0224, 8, 43.6-55.4 mm standard length, Sistan, Hirmand River effluent (30º53'30"N, 61º27'E); CMNFI 1979-0226, 277, 29.7-78.8 mm standard length, Sistan, pool near Kuh-e Khajeh (30º57'N, 61º17'E); CMNFI 1979-0227, 4, 37.0-48.9 mm standard length, Sistan, neizar at Kuh-e Khajeh (30º57'N, 61º16'E); CMNFI 1979-0228, 1, 42.9 mm standard length, Sistan, ditch 1 km from Zabol (31º02'30"N, 61º31'E); CMNFI 1979-0229, 5, 52.3-93.2 mm standard length, Sistan, ditch 5 km from Zabol (31º03'N, 61º33'E); CMNFI 1979-0230, 1, 48.3 mm standard length, Sistan, Hamun-e Puzak (ca. 31º15'N, ca. 61º42'E); CMNFI 1979-0232, 9, 44.0-65.9 mm standard length, Sistan, ditch 11 km from Zabol (ca. 30º58'30"N, ca. 61º36'E); CMNFI 1979-0234, 17, 40.4-49.3 mm standard length, Sistan, effluent of Hirmand River near Zahak (30º54'N, 61º40'E); CMNFI 1979-0237, 1, 34.3 mm standard length, Sistan, ditch 18 km south of Zabol (30º53'N, 61º27'30"E); CMNFI 2008-0204, 3, 68.1-79.1 mm standard length, Sistan (no other locality data).

Sistan, Kuh-e Khajeh
(Mount Khajeh Panorama …. in Farsi, CC BY-SA 4.0, Ahmad.Abbasi.m).

***Tariqilabeo diplochilus***
(Heckel, 1838)



*Tariqilabeo diplochilus* (as the synonym *Crossocheilus barbatulus*), after Beavan (1872).

*Tariqilabeo diplochilus*, Baluchestan, Sarbaz River, after Jouladeh-Roudbar *et al*. (2020).

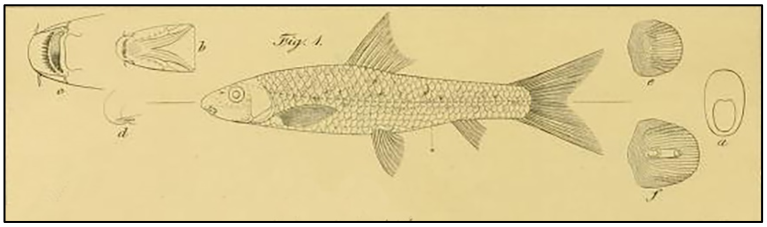
*Tariqilabeo diplochilus*, Baluchestan, Zirdan Dam, Kaju River,
26 December 2011, Asghar Mobaraki.

**Common names.** Sanglise Keshmir (= Kashmir slippery rock fish).

[Chhoti reti, dogra or ispigoar in Pakistan; Kashmir latia, slaty algaeater].

**Systematics.** *Barbus diplochilus* was described from Kashmir and has been placed as a subspecies of *Cyprinus latius* Hamilton, 1822, described from the Tista River in

India/Bangladesh. The species name is sometimes spelled *diplocheilus*, incorrectly. The *Catalog of Fishe*s (downloaded 28 May 2019) lists seven syntypes for *Barbus diplochilus* under NMW 48820. No types were known for *Cyprinus latius* (Eschmeyer *et al*., 1996) but Ciccotto and Page (2016) designated a neotype in the California Academy of Sciences under CAS-SU 69910. Jouladeh-Roudbar *et al*. (2020) give the author as McClelland, 1839 which is incorrect.



*Barbus diplochilus*, syntype, after Heckel (1838).

**Key characters.** This species is distinguished from its relative in Iran by having one or two pairs of short barbels (rostral barbel 1.2-2.8% standard length, 5.5-11.4% head length, maxillary barbel 0.3-0.9% standard length, 1.4-4.1% head length), total gill rakers usually 23-25 and scales between anus and anal fin 2-3 (Sayyadzadeh *et al*., 2015).

**Morphology.** The body is deeper than in *T. adiscus* (22.3-29.5% standard length compared to 18.5-22.1%) but very similar in other respects (*q.v.*). The body is rounded and the dorsal profile in front of the dorsal fin falls gradually to the rounded snout. The eye lies at the mid-head or slightly anterior. The subterminal mouth gape is a shallow arch and the chin is papillose. Lips are thin. Four short and thin barbels are present, the rostral ones longer than those at the mouth corner, and the latter barbels sometimes absent. The caudal peduncle is compressed and relatively deep. The dorsal fin is emarginate and its origin is well anterior to that of the pelvic fin. Its tip when appressed does not reach back to the anal fin origin. The anal fin margin is rounded and the fin does not reach back to the caudal fin base. The caudal fin is deeply forked with pointed tips. The pelvic fin margin is rounded and the fin extends back to the anus (which is anterior to the anal fin origin). The pectoral fin is rounded and does not extend back to the pelvic fin. Illustrations of the swim bladder are given in Sayyadzadeh *et al*. (2015).

Dorsal fin unbranched rays 2-3 and branched rays 8-9, modally 8, anal fin unbranched rays 2-3 and branched rays 4-5, modally 5, pectoral fin branched rays 14-17, and pelvic fin branched rays 7-10, modally 8. Lateral line scales 33-41. Scales may have short dorsal and ventral projections from the margin at about one-third of the scale length from the posterior edge. There is a pelvic axillary scale. Scales are similar to those in *T. adiscus*. Total gill rakers number 20-25, and are small, reaching the adjacent or second raker when appressed. Su *et al*. (2000) gave a gill raker count of 17-21 (possibly lower arch only). Pharyngeal teeth are usually 3,3,5-5,3,3 or 2,4,5-5,4,2, depending on how the crowded teeth are counted. The crown of major row teeth is flattened, the anterior tooth may be rounded and some teeth may have a small hooked tip. The gut is very long and complexly coiled. Total vertebrae number 35-36. The chromosome number is probably 2n = 48 (Klinkhardt *et al*., 1995).

Iranian fish from Baluchestan have the following meristic characters:- dorsal fin branched rays 8(4), anal fin branched rays 5(4), pectoral fin branched rays 16(4), pelvic fin branched rays 7(1) or 8(3), lateral line scales 33(1), 34(1), 35(1) or 36(1), and total gill rakers 20-23, but not countable with great accuracy since the smallest rakers are difficult to detect at

the ends of the arch.

**Sexual dimorphism.** Unknown.

**Colour.** The back is brownish to greenish, the flanks silvery and the belly light pink to yellowish-white or silvery-white. Paired fins are yellow to pink and the dorsal and caudal fins have a grey tinge. The anal fin can be whitish or grey. There is a broad stripe along the back mid-line. The peritoneum is black.

**Size.** Attains 17.3 cm total length.

**Distribution.** This species is found in submontane areas of Afghanistan, Pakistan and India as well as southeastern Iran. In Iran, it is found in the Hamun-e Mashkid basin including the Mashkid, Simish and Sirkan rivers and in coastal streams of the Makran from the Jaghin to middle and upper Nikshahr rivers and the middle and upper Bahu Kalat River including its Sarbaz River reach, and in the Zirdan Dam on the Kaju River (Berg, 1949; J. Holčík, *in litt*., 1996; Abdoli, 2000; Malekzehi *et al*., 2014; K. Abbasi, see photograph above).

**Zoogeography.** This distribution in Iran marks the western limit for the genus and the relationships of the species lie to the east.

**Habitat.** This species is found in rivers, streams, dams and qanats and has been collected in isolated pools of dried river beds (CMNFI 1979-0333). It is less common in Baluchestan streams than its relative in Sistan. Asghar Mobaraki (pers. comm., 8 January 2012) recorded a fish kill of this species on 26 December 2011 at the Zirdan Dam construction site on the Kaju River. Collection data included a temperature range of 15-24ºC, pH 6.0-6.2, conductivity 0.45-1.5 mS, river width 8-80 m, still to medium current, river depth 35-40 cm, clear or muddy water, mud, pebble, boulders or bedrock bottoms, encrusting algae and grassy shores.

Habitat of *Tariqilabeo diplochilus*, Baluchestan, Zirdan Dam, Kaju River, 26 December 2011, Asghar Mobaraki.

Tekrival and Rao (1999) reported its aquarium preferences as 18-22°C, pH 6.5-7.2, algae as food, not too bright lighting, bottom dwelling with stones, roots and crevices preferred and cave brooding reproduction. Field collections have been made at 24°C on 2 December

1977 in the Sarbaz River, Baluchestan (CMNFI 1979-0318).

**Age and growth.** Esmaeili *et al*. (2014) gave a *b* value for 21 fish from the Makran, 3.65-10.56 cm total length, as 3.02.

**Food.** Diet is algae on muddy bottoms. It is a bottom feeding herbivore taking more than 90% plant food such as algae, diatoms and macrophytes as well as detritus (Sharma, 1984; Singh and Bahuguna, 1984). Detritus and some insect remains, possibly as accidental inclusions, were found in fish from the Northwest Frontier Province of Pakistan (Butt and Khan, 1987). In the Punjab, it was reported as sticking to stones, presumably feeding by scraping (Khan, 1934).

**Reproduction.** Unknown.

**Parasites and predators.** Jalali *et al*. (2000) described two new species of monogenean, *Dactylogyrus eslamii* and *D. faridpaki* from this species in the Bahu Kalat River of Baluchestan. Malekzehi *et al*. (2013, 2014) recorded *Lernaea* sp. from fish in the Mashkel River basin.

**Economic importance.** This species is of no economic importance although Butt (1995) suggested it could be cultured as food and as a forage fish in Pakistan.

**Experimental studies.** None.

**Conservation.** Not as common in Baluchestan as its relative is in Sistan, its status is unknown.

**Sources.** Iranian material:- CMNFI 1979-0318, 2, 24.0-27.8 mm standard length, Baluchestan, Sarbaz River at Huvar (26º09'N, 61º27'E); CMNFI 1979-0333, 2, 20.8-21.2 mm standard length, Baluchestan, Mashkid River west of Kuhak (ca. 27º05'N, ca. 63º12'E); CMNFI 1979-0334, 3, 11.8-19.9 mm standard length, Baluchestan, Mashkid River 5 km east of Esfandak (27°04'N, 62°54'E).

Comparative material:- CMNFI 2008-0048A, 2, 47.6 mm standard length, Afghanistan, probably Kabul River basin (no other locality data); CMNFI 2009-0029, 1, 53.0 mm standard length, Afghanistan, Kabul River (34°28'35"N, 70°22'24"E); CMNFI 2009-0030, 1, 51.7 mm standard length, Afghanistan, Kabul River (34°28'43"N, 70°22'18"E).

# Bibliography

Literature sources on the Carps and Minnows of Iran and their environment appear at the end of "Volume II: Minnows (Family Leuciscidae) and Bibliography".

# Carps and Minnows of Iran

This work provides a guide and general overview of two important freshwater fish families in Iran, the Carps (Cyprinidae) and the Minnows (Leuciscidae). There is also an extensive General Introduction covering Materials and Methods, Environment (Geography, Climate, Habitats, Drainage Basins), History of Research and Fisheries. In addition there are Checklists of Species, Identification Keys and a section on Biodiversity.

The work is illustrated by over 1800 line drawings and colour images of fish and habitats. The extensive Bibliography covers the two fish families and related Iranian families as well as the Iranian environment and has over 6800 references.

The Carp Family in Iran contains 14 native genera and 66 species with 3 exotics. Twenty-five species are endemics. The Minnow Family contains 14 native genera and ca. 47 species with 21 species endemics. Some species are members of the charismatic megafauna, commercially important or of cultural significance, and all are a significant component of the Iranian freshwater ichthyofauna and ecosystems.

Each species account comprises line drawings and colour photographs of the fish, common names, systematics, key characters, morphology, sexual dimorphism, colour, size, distribution, zoogeography, habitats and some habitat photographs, age and growth, food, reproduction, parasites and predators, economic importance, experimental studies, conservation and sources. This information is based on literature, field observations and museum specimens.

Volume 1 comprises the General Introduction and the Carp Family and Volume 2 the Minnow Family and the Bibliography.

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